REFRACTION OF THE HUMAN EYE

AND

METHODS OF ESTIMATING THE REFRACTION

THORINGTON

Refraction of the Human Eye

AND

Methods of Estimating the Refraction

INCLUDING A SECTION ON THE FITTING OF SPECTACLES AND EYE-GLASSES, ETC.

BY

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PREFACE

"Refraction of the Human Eye and Methods of Estimating the Refraction" is an amalgamation of the Author's works, "Refraction and How to Refract," "Prisms" and "Retinoscopy." and is issued to satisfy the constant and increasing demand for such a work in one volume.

The contents of the above-named books have been rearranged and coordinated by amplifications, modifications or deletions, so as to produce a book suitable for all beginners in Ophthalmology, and particularly for those who have a limited knowledge of mathematics and who cannot readily appreciate the classic treatise of Donders. The writer has planned to be systematic and practical, so that the student, starting with the consideration of rays of light, is gradually brought to a full understanding of optics; and following this, he is taught what is the Standard Eye, and then is given a description of ametropic eyes, with a differential diagnosis of each, until finally he is told how to place lenses in front of ametropic eyes to make them equal to the standard condition. By being dogmatic rather than ambiguous; by occasional repetitions to avoid frequent references, and by simple explanations and a definite statement of facts, the writer has aimed to make the text concise and comprehensive, consequently, there are no lengthy mathematic formulas or any discussion of disputed points.

For three reasons the heading "Retinoscopy" for Chapter X has been chosen to describe that method of estimating the refraction, namely:

First, that it may not be confounded with Skiagraphy.

Second, that it is the name by which the test is universally known; and

Third, that it is the Retina in its relative position to the dioptric media which we study.

The chapter on Prisms has been very much enlarged, as the average book on Ophthalmology gives but little information on this branch of refraction, and, to make it more entertaining, the writer has not limited himself to the consideration of prisms in ophthalmic practice alone, and has inserted many illustrations to make the text easy of comprehension. The Author's double prism, a new and delicate test, for the detection of errors of muscular imbalance whether of small or great amount, is incorporated in the text. Among the other entirely new matter in this book mention may be made of Retinoscopy without a cycloplegic (Chapter XX). Among the deletions are: Scheiner's Test; The Pointed Line Test; The Chromo-aberration Test, and Thomson's Ametrometer, all of which are out of date and relegated to the historical.

Many of the illustrations were drawn or photographed by the Author, and the diagrams of astigmatic eyes, as also several others, are original.

A Chinese Edition of "Refraction and How to Refract," translated by Dr. James H. Ingram of Tungchou, China, was published in October, 1914.

This volume goes forth with the Author's grateful appreciation of the numerous complimentary recognitions accorded the former works, and with the hope that it may receive similar favor.

J. T.

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CONTENTS

REFRACTION OF THE HUMAN EYE

AND

METHODS OF ESTIMATING THE REFRACTION

CHAPTER I

OPTICS

Optics (from the Greek ὄπτομαι, meaning "to see") is that branch of physical science which treats of the nature and properties of light.

Catoptrics (from the Greek κάτοπτρον, meaning "a mirror") and **dioptrics** (from the Greek δίοπτρον, meaning "to see through") are subdivisions of optics; the former treating of incident and reflected rays, and the latter of the refraction of light passing through different media, such as air, water, glass, etc., but especially through lenses.

Light.—Light may be defined as that form of energy which, acting upon the organs of sight, renders visible the objects from which it proceeds. This form of energy is propagated in waves in all directions from a luminous body, and with a velocity in a vacuum of about 186,000 miles a second. In the study of a luminous body, such as a candle-, lamp-, or gas-flame, the substance itself must not be considered as a single source of radiation, but as a collection of minute points, from every one of which waves proceed in all directions and cross one another as they diverge from their respective points. **The intensity** of light decreases as the square of the distance from the light increases; for example, if an object is twice as far from a lumi-

nous body as another of the same size, it will receive one-fourth as much light as the latter. Figure 1 shows two cards, one is twice as far from the light as the other and receives only one-fourth as much light as the card nearest to the light.

Ray.—Ray (from "radius") is used in optics in preference to wave, and means the smallest subdivision of light traveling in a straight line. Light rays occur in three forms only and they are defined or described according to the positions which they bear toward each other, namely, divergent, parallel and convergent.

Divergent Rays.—Rays of light proceed divergently from any luminous substance, but, in the study of refraction, only those which proceed from a point closer than 6 meters are spoken of as divergent (Fig. 4).

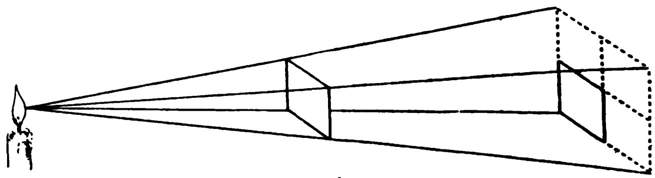

FIG. 1.—Illustrating intensity of light.

Parallel Rays.—The greater the distance of any luminous point, the more nearly do its rays approach to parallelism; this is evident in a study of rays coming from such distant sources as the sun, moon, and stars. For all practical purposes in the study of refraction, rays of light which proceed from a distance of 6 meters or more are spoken of as parallel, although this is not an absolute fact, as rays of light at this distance still maintain a slight amount of divergence. If the pupil of the emmetropic eye is represented by a circular opening 4 mm. in diameter, then rays of light from a luminous point at 6 meters (6000 mm.) will have a divergence of $4/6000$ when they enter such a pupil.

Convergent Rays.—Convergent rays are the result of reflection from a concave mirror or refraction through a convex lens (see Figs. 2 and 3).

These three forms of light rays are further considered as incident, emergent, reflected and refracted, but the student must not think from this that there are more than three forms of light rays. He must remember that we may have divergent, parallel and convergent rays appearing as incident, emergent, reflected and refracted rays. Or we may make the reverse statement, that incident, emergent, reflected and refracted rays are either divergent, parallel or convergent.

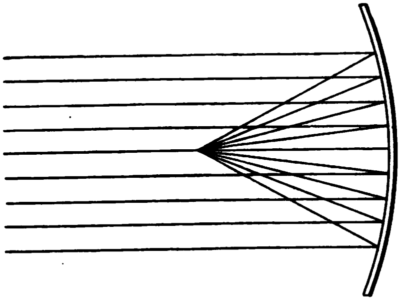

FIG. 2.—Incident parallel rays reflected by a concave mirror forming a convergent pencil.

Incident Rays.—Rays of light are said to be incident when they strike the surface of an object (see Figs. 2, 3 and 8).

Emergent Rays.—Rays of light are emergent when they have passed through a transparent substance (see Fig. 13).

Reflected Rays.—Rays of light are reflected when they rebound from a polished surface (see Fig. 8).

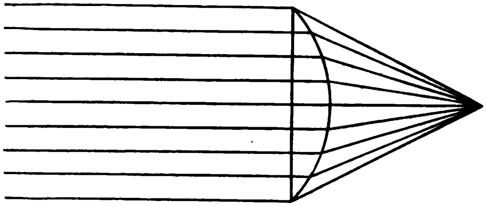

FIG. 3.—Incident parallel rays refracted by a convex lens forming a convergent pencil.

Refracted Rays.—A ray of light undergoes refraction when it is deviated from its course in passing through any transparent substance.

A Beam.—This is a collection or series of parallel rays (see Fig. 3).

A Pencil.—A pencil of light is a collection of convergent or divergent rays. Convergent rays are those which tend to a common point (see Fig. 3), whereas divergent rays are those which proceed from a point and continually separate as they proceed (see Fig. 4). This point is called the radiant point.

A Focus.—This is the point of a convergent or divergent pencil; the center of a circle; the point to which converging rays are directed.

A Positive or Real Focus.—This is the point *to which* rays are directed after passing through a convex lens or after reflection from a concave mirror (see Figs. 3 and 2).

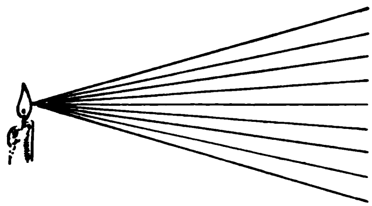

FIG. 4.—Illustrating a divergent pencil.

A Negative or Virtual Focus.—This is the point *from which* rays *appear* to diverge after passing through a concave lens (see Fig. 82), or after reflection from a convex mirror, or after refraction through a convex lens when the light or object is closer to the lens than its principal focus (see Fig. 89), or after reflection from a concave mirror when the light or object is closer to the mirror than its principal focus (see Fig. 8).

Infinity.—(Latin, *Infinitus—in*, not, and *finis*, limit.) Unlimited extent of space. Infinity is abbreviated by the sign, ∞.

Medium in ophthalmology means a substance through which light is transmitted.

The principal phenomena of light are *absorption*, *reflection*, and *refraction*.

Absorption.—Rays of light from the sun falling upon the green grass are partly absorbed and partly reflected. The grass absorbs some of the rays and sends back or reflects only those rays which together produce the effect of green. A piece of red glass owes its color to the fact that it transmits only that portion of the light's rays whose combined effect upon the retina is

that of red. The relative proportion of absorption and reflection of rays of light depends greatly upon the quality of the surface—whether light colored or polished, or dark colored or rough.

Reflection.—From the Latin *reflectere*, to "rebound." This is the sending back of rays of light by the surface on which they fall into the medium through which they came. While most of the rays falling upon the surface of a transparent substance pass through it, with or without change in their direction, yet some of the rays *are* reflected, and it is by these reflected rays that surfaces are made visible. A substance that could transmit or absorb all the rays of light coming to it (if such a substance existed) would be

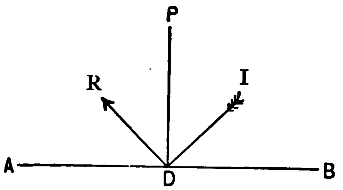

FIG. 5.

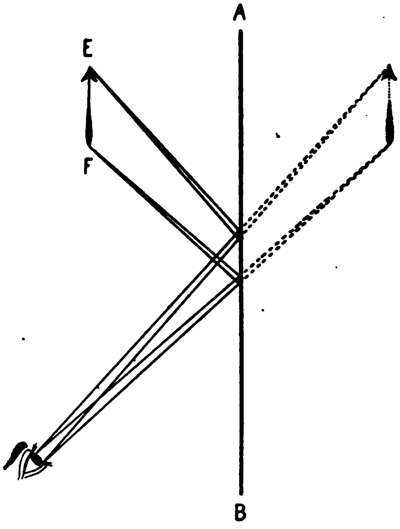

FIG. 6.

invisible. Reflection, therefore, always accompanies refraction (see Fig. 13), and, if one of these disappear, the other will disappear also.

Laws of Reflection.—(1) The angle of reflection is equal to the angle of incidence (see Fig. 5). (2) The reflected and incident rays are in the same plane with the perpendicular to the surface (see Fig. 5).

If AB represent a polished surface and I the incident ray, then PDI is the angle of incidence; R being the reflected ray, then

PDR, equal to it, is the angle of reflection. ID, PD and RD lie in the same plane.

A reflecting surface is usually a polished surface (a mirror), and may be plane, concave, or convex.

Reflection from a Plane Mirror.—Rays of light are reflected from a plane mirror in the same direction in which they fall upon it: if parallel, convergent, or divergent before reflection, then they are parallel, convergent, or divergent after reflection. An object placed in front of a plane mirror appears just as far back in the mirror as the object is in front of it (see Fig. 6).

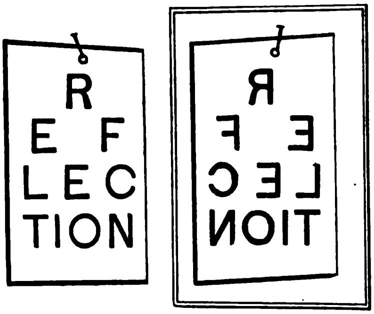

FIG. 7.—Lateral inversion.

AB represents a plane mirror with EF, rays from the extremes of the arrow, reflected from the mirror AB, and falling on the observer's eye as if they came from the arrow in the mirror (see Visual Angle, page 100). The apparent distance of the arrow from the observer is equal to the combined length of the incident and reflected rays.

The *appearance* of an image in a plane mirror is not exactly the same as that of the object facing the mirror: it undergoes what is known as lateral inversion. This is best understood by holding a printed page in front of a plane mirror, when the words or letters will read from right to left (see Fig. 7). An observer facing a plane mirror and raising his right hand, his image apparently raises the left hand.

Tilting a plane mirror gives an object the appearance of moving in the opposite direction to that in which the mirror is tilted.

Spheric Mirrors.—A spheric mirror is a portion of a reflecting spheric surface; its center of curvature is therefore the center of the sphere of which it is a part. Spheric mirrors are of two kinds—concave and convex.

Reflection from a Concave Mirror (Fig. 8).—Parallel rays are reflected from a concave mirror, and are brought to a focus in front of it. This point is called the principal focus (P.F.). The principal axis of a concave mirror is a straight line drawn from the mirror through the principal focus and the center of curvature (1–1), and a secondary axis (2′, 2′, 2′, 2′) is any other straight line passing from the mirror to the center of curvature (C.C.). Rays which diverge from any point beyond the principal focus are reflected convergently (GJ). Rays which diverge from any point closer than the principal focus are reflected divergently (VV′).

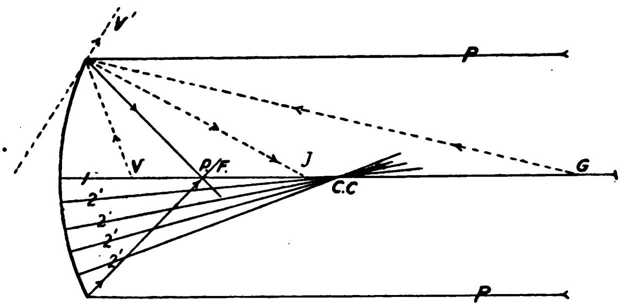

FIG. 8.

Images Formed by a Concave Mirror.—To find the position of an image as formed by a concave mirror, two rays may be used: one drawn from a given point on the object to the mirror, and parallel to its principal axis, and reflected through the principal focus (P.F., Figs. 9 and 10); the other, the secondary axis, from the same point, passing through the center of curvature. The place where the secondary axis and the reflected ray or their projections intersect gives the position of the image. Unlike the plane mirror, which produces images at all times and at all distances, the concave mirror produces either an erect, virtual, and enlarged image, if an object is placed closer than its princi-

pal focus, or an enlarged inverted image if the object is between the principal focus and the center of curvature.

By withdrawing the mirror in the former instance the erect image increases slightly in size, and in the latter the inverted image diminishes in size. At the principal focus there is no image formed.

Figure 9 shows an erect, virtual, and enlarged image of AR which is closer to the mirror than the principal focus. Parallel rays from A and R are reflected to the principal focus, P.F. Lines drawn from the center of curvature through A and R to the mirror are secondary axes; these lines and those reflected

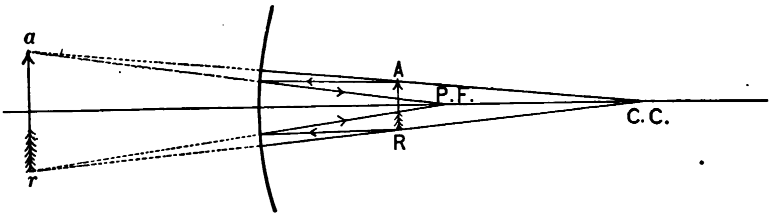

FIG. 9.

to the principal focus do not intersect in front of the mirror, but if projected, will meet at *a* and *r* behind the mirror, forming a magnified image of AR. If the mirror is withdrawn from the object, the erect magnified image will increase in size, but at the principal focus no image will be formed, as the rays are reflected parallel.

Figure 10 shows a real inverted image of AR at *ar*; AR situated beyond the principal focus. Lines drawn from A and R through C.C. are secondary axes. Parallel rays from A and R converge and cross at the principal focus (P.F.).

Where DP and FE intersect the secondary axes, the inverted image *ar* of AR is situated. When the object, as in this instance, is situated beyond the center of curvature, the image is smaller than the object. As the image and object are conjugate to each other, they are interchangeable, and in such a case the

image would be larger than the object and inverted. This is always true when the object is situated between the center of curvature and the principal focus. When an object is situated at the center of curvature, its image is equally distant and of the same size, but inverted.

Tilting a concave mirror gives an object placed inside of its principal focus the appearance of moving as the mirror is tilted; but if the object is situated beyond the principal focus, the object appears to move in the opposite direction.

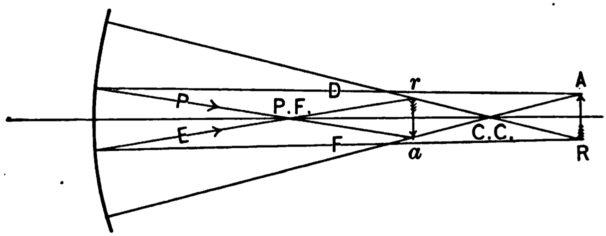

FIG. 10.

Reflection from a Convex Mirror.—All rays are reflected divergently from a convex mirror, and parallel rays diverge as if they came from the principal focus situated behind the mirror at a distance equal to one-half its radius of curvature. The principal focus of a convex mirror is therefore negative. The foci of convex mirrors are virtual.

Images Formed by a Convex Mirror.—These are always virtual, erect, and *smaller* than the object. The closer the object, the larger the image; and the more distant the object, the smaller the image. Tilting a convex mirror, the image, does not appear to change position.

In Fig. 11 parallel rays from the object AR are reflected from the mirror as if they came from the principal focus situated at one-half the distance of the center of curvature, C.C. Lines drawn from the extremes of the object to C.C. are secondary axes, and the image is situated at the point of intersection of the secondary axes and the rays from the principal focus; and

as these meet behind the mirror, the image is virtual and erect.

Refraction.—From the Latin *refrangere,* meaning "to bend back"—*i.e.*, to deviate from a straight course. Refraction may be defined as the deviation which takes place in the direction of rays of light as they pass from one medium into another of different density.[1]

Two laws govern the refraction of rays of light:

1. A ray of light passing from a rare into a denser medium is deviated or refracted *toward* the perpendicular.

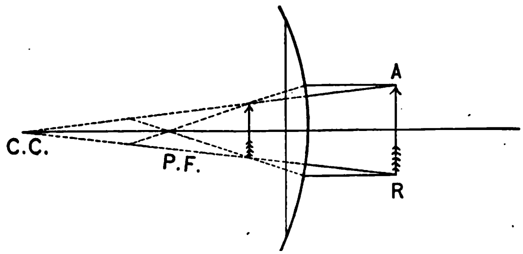

FIG. 11.

2. A ray of light passing from a dense into a rarer medium is deviated or refracted away *from* the perpendicular.

Aside from these laws, there are other facts in regard to rays of light that should have consideration. A ray of light will continue its straight course through any number of different transparent media, no matter what their densities, so long as it forms right angles with the surface or surfaces. Such a ray is spoken of as the normal or perpendicular; such surfaces are plane, the surfaces and perpendicular forming right angles (see Fig. 12). In any case of refraction the incident and refracted rays may be supposed to change places.

Figure 13 shows the perpendicular (PP) to a piece of plate

[1] As ordinarily understood in ophthalmology, refraction has come to mean the optic condition of an eye in a state of repose or under the physiologic effect of a cycloplegic.

glass with plane surfaces. Part of the ray A in air incident at O on the surface SF is bent in the glass *toward* the perpendicular, PP. The dotted line shows the direction the ray would have taken had it not been refracted. As the ray in the glass comes to the second surface at R, and passes into a rarer medium, it

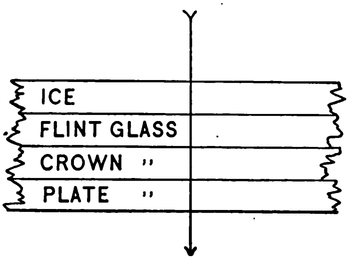

FIG. 12.

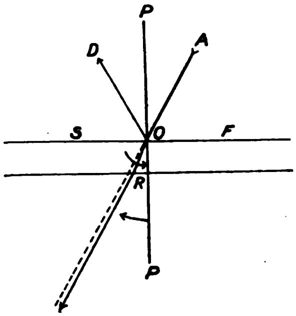

FIG. 13.

is deviated *from* the perpendicular, PP. The ray now continues its original direction, but has been deviated from its course; it has undergone lateral displacement. Attention must be directed to the thickness of the incident ray A in this same Fig. 13; as it falls upon the surface SF, only part of it is refracted,

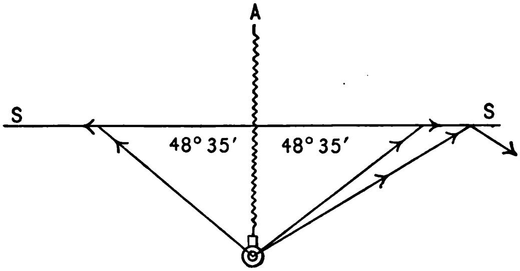

FIG. 14.—Critical angle.

and part of it is reflected; the reflected ray is marked D (see reflection, page 5).

Critical Angle or Limiting Angle of Refraction.—This is the angle of incidence which just permits a ray of light in a dense

medium to pass out into a rare medium. The size of the critical angle depends upon the index of refraction of different substances. Figure 14 shows an electric light suspended in water. The ray from this light which forms an angle of 48° 35′ with the surface of the water will be refracted and pass out of the water, grazing its surface; but those rays which form an angle greater than 48° 35′ will not pass out of the water, but will be reflected back into it. The surface separating the media becomes a reflecting surface and acts as a plane mirror.

The critical angle for crown glass is 40° 49′.

Index of Refraction.—By this is meant the relative density of a substance or the comparative length of time required for light to travel a definite distance in different substances. Or the index of refraction may be defined as the reciprocal of the decrease of the speed of light as it passes from space into a transparent medium. **The absolute index** of refraction is the density or refractive power of any substance as compared with a vacuum. According to the first law of refraction, a ray of light passing from a rare into a dense medium is refracted toward the perpendicular; in other words, the angle of refraction is smaller, under these circumstances, than the angle of incidence. In the study of the comparative density of any substance it will be seen that the angle of refraction is usually smaller the more dense the substance; this is well illustrated in Figs. 15 and 16.

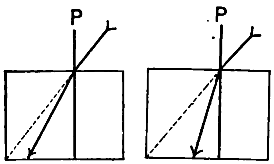

FIG. 15. FIG. 16.

The greater the density, the slower the velocity or the more effort apparently for the wave or ray to pass through the substance. This is illustrated in Fig. 17, where a ray or wave of light is seen passing at right angles through different media. A ray passes through a vacuum without apparent resistance, but in its course through air it is slightly impeded, so that air has an index of refraction of 1.00029 + when compared with a vacuum;

but as this is so slight, air and a vacuum are considered as one for all purposes in ophthalmology. To find the index of refraction of any substance as compared with a vacuum or air, it is necessary to divide the sine of the angle of incidence by the sine of the angle of refraction.

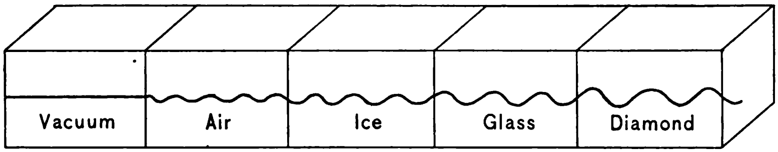

FIG. 17.

In Fig. 18 the angle of incidence PCI is the angle formed by the incident ray I with the perpendicular, PP. The angle of refraction PCR is the angle formed by the refracted ray with the perpendicular, PP. Drawing the circle PHPO around the point of incidence C, and then drawing the sines DX and BF,

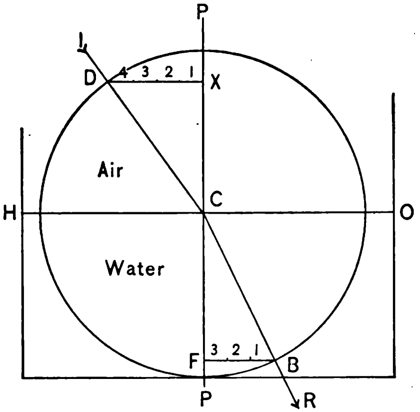

FIG. 18.

perpendiculars to the perpendicular PP, divide the sine DX of the angle of incidence by the sine FB of the angle of refraction to obtain the index of refraction; in this instance, water as compared with air. DX equaling 4 and FB equaling 3, then 4

divided by 3 will equal $4/3$, or 1.33 +, the index of refraction of water as compared with air.

To find the index of refraction of a rare as compared with a dense substance, divide the sine of the angle of refraction by the sine of the angle of incidence—*i.e.*, air as compared with water would be $3/4$, or 0.75.

INDICES (INDEXES) OF REFRACTION

Air	1.00029
Water	1.333
Cornea	1.3333
Crown glass	1.5
Flint glass	1.58
Crystalline lens, nucleus	1.43
Crystalline lens, intermediate layer	1.41
Crystalline lens, cortical layer	1.39

PRISMS

CHAPTER II

GENERAL DESCRIPTION

A Prism is a wedge-shaped portion of a refracting medium (usually of glass) contained between two plane polished surfaces (Figs. 19, 20, 21 and 23), or a prism is a transparent homogeneous medium with two plane surfaces which are not parallel to each other. Prisms used in the practice of ophthal-

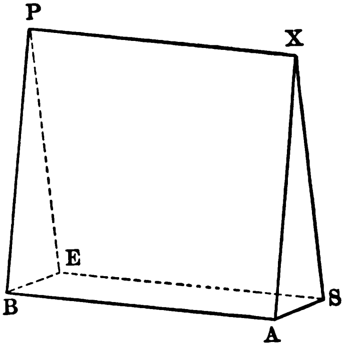

FIG. 19.—Prism on base. PX = Edge or Apex. BASE = Base. PBAX and PESX = Faces or Surfaces. BPE and AXS = Angle.

mology are seldom very strong and therefore have their surfaces placed at a very acute angle.

The sides of a prism are the inclined surfaces, also spoken of as *refracting surfaces* or *faces* (PBAX and PESX in Figs. 19, 20 and 21).

The edge (also frequently spoken of as the *apex* of a prism)

is that part of the prism where the two plane surfaces meet (PX in Figs. 19, 20 and 21).

The base of a prism is the thick part of the prism and is opposite to the edge or apex (BASE in Figs. 19, 20 and 21).

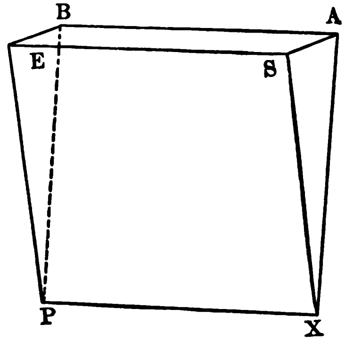

FIG. 20.—Prism on edge. PX = Edge or Apex. BASE = **Base.** PBAX and PESX = Faces or Surfaces. BPE and AXS = **Angle.**

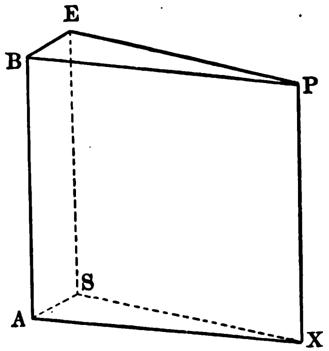

FIG. 21.—Prism on side. PX = Edge or Apex. BASE = **Base.** PBAX and PESX = Faces or Surfaces. BPE and AXS = **Angle.**

The base of the prism is occasionally referred to as **the third** surface.

The refracting angle is a physical feature of the prism and is the angle at which the two sides or refracting surfaces come together; it is this angle together with the index of refraction of

the glass (or medium) which determines the strength of the prism (BPE and AXS in Figs. 19, 20 and 21).

Section of a Prism.—Dividing or cutting through a prism at right angles to its refracting surfaces or faces makes a *principal*

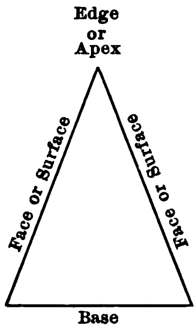

FIG. 22.—Principal section of a prism.

section; this is shown in Fig. 22, and will assist in explaining what has just been described.

Shape or Form of a Prism.—By this is meant the outline or contour of the prism and not the section, this latter being wedge shaped (Fig. 22). Figures 19, 20 and 21 illustrate square

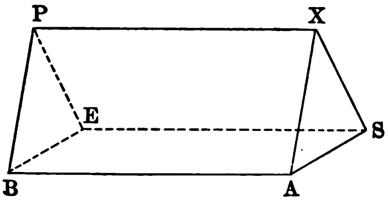

FIG. 23.—Rectangular prism.

prisms; Fig. 23, a rectangular prism; and Figs. 25, 26 and 27, round prisms. Rectangular prisms are not ordinarily used in ophthalmology. Square prisms, while easily handled, cannot be placed in the ordinary trial-frame.

The late Dr. Noyes recommended a battery of prisms which was a series of small square prisms of increasing strength, num-

bered in degrees, ½, 1, 2, 3, 4 and 6, mounted in a frame as shown in Fig. 24. The operator or patient held this vertically in front of the eye and moved it up or down when it was desired to get a stronger or weaker prism before the eye. Two of these batteries or "bars" were required, one with the bases of the prisms placed laterally and the other with the bases placed vertically. These batteries of prisms are not in general use.

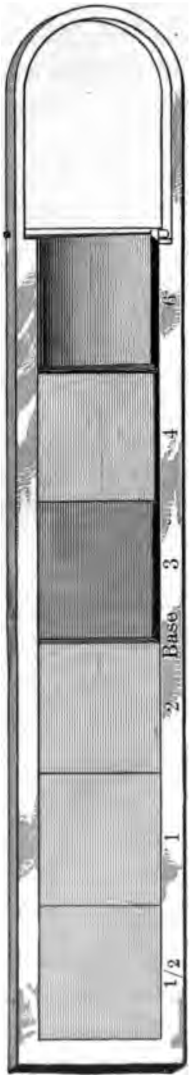

FIG. 24.—Dr. Noyes' prism bar or battery.

Round or Circular Prisms (Figs. 25, 26 and 27).—These are found in the trial-case and as their diameters (set in cells) are the same as the spheres and cylinders, they fit easily into the trial-frame. Unfortunately the base of the prism being quite thick in some instances (Fig. 28) takes up considerable space in the trial-frame and therefore when in the frame it has to be placed in the outer opening, so as to leave room for the sphere and cylinder back of it. If placed in the back opening of the frame it is liable to rub against the eye lashes or the eyelid.

Recognition of the Edge or Apex and Base of the Prism.—When a prism is square (Fig. 19) in contour its long edge or apex is immediately and easily detected and likewise its base (Fig. 25), but when round or circular (Figs. 26 and 27) in contour, its thinnest part will then be recognized as a point in the apex or edge of the original square prism (Fig. 25). The thickest part or base of the round or circular prism is diametrically opposite to the edge or apex and it too corresponds to a point or line in the base of the

original square prism (Fig. 25). These two points indicating the edge (or apex) and base of a round or circular prism are marked with a broad diamond scratch on the glass (Fig. 26) the same as seen on cylinder lenses, to indicate the axis of the

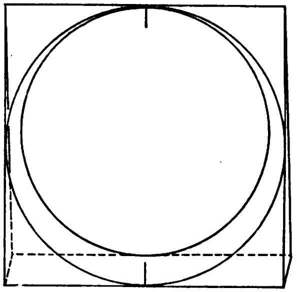

FIG. 25.—Square prism marked for cutting out the round or circular prism.

cylinder. Likewise the number of the prism is also scratched upon the glass. The position of the base of a circular prism is occasionally marked with a white or black line connecting the two plane (circular) surfaces or faces at their greatest separated points (Fig. 25). This method of marking the posi-

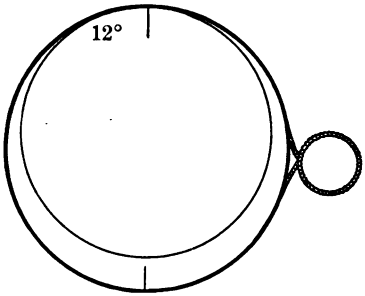

FIG. 26.—Prism in wire frame. Diamond scratches on glass to indicate base and apex line, also number of prism.

tion of the prism edge, base and number, does not meet with the writer's approval, as they are not sufficiently distinct, and he therefore has the prisms in his own trial-case marked as shown in Fig. 27. These prisms have very wide black metal frames

without handles, the wide frame or cell acting as a handle. The direction of the edge and number of the prism are marked in white on this black metal frame as shown in the figures referred to and the base is indicated by an arrow head, also marked in white.

Base-apex Line.—This is an imaginary straight line connecting the edge (apex) with the center of the base (AB in Fig. 29). This base-apex line is of as great importance to a knowledge and use of prisms as the axis line of a cylinder lens. In Chapter III it will be shown that an object viewed through a prism always appears displaced in the direction of the edge of the prism and exactly parallel to the base-apex line (Fig. 37).

FIG. 27.—Prism with wide frame showing markings of base and apex and number on frame or cell.

The Axis of a Prism.—This is an imaginary straight line midway between the edge and the base and at right angles to the base-apex line, therefore parallel to the edge (XS in Fig. 29).

The Plane of a Prism.—This is midway between the two plane surfaces, bisecting the angle of the prism (Fig. 29).

Position of a Prism.—When a prism is placed in front of an eye its position is indicated or described by the direction of the base which must always be carefully specified in the prescription. *Base down* means that the thickest part of the prism is toward the cheek; this is written in the prescription, Base down. *Base up* means that the base-apex line is still vertical but the

base is directed upward or toward the brow, and this is written in the prescription, Base up. *Base in* means that the base-apex line is horizontal and the base of the prism toward the nose; this is written in the prescription, Base in. *Base out* means that the base-apex line is horizontal and the base of the prism is toward the temple; this is written in the prescription, Base out.

The base of the prism may be placed in any desired direction, but the prescriber must specify definitely in his prescription: (1) the strength of the prism, (2) which eye the prism is for, and (3) whether the base is up, down, in or out; or up and in, or

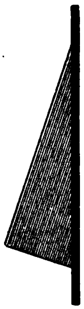

FIG. 28.—Profile view of Fig. 27.

up and out, or down and in, or down and out; for instance, the following:

Right Eye, 2 Prism base down meridian of the base-apex line 75°; 2 Prism base up meridian of the base-apex line 75°; 2 Prism base down meridian of the base-apex line 45° or 2 Prism base down and out meridian of the base-apex line 45°; 2 Prism base up meridian of the base-apex line 135° or 2 Prism base up and out meridian of the base-apex line 135°, etc. The reader may obtain a clearer idea on this point by referring to the arrow marking on the cell of the prism pictured in Fig. 27, and if he will place a prism in a trial-frame and study it in the positions just described he will

obtain a definite knowledge of the position of prisms before the eye.

The prisms in the trial-case are made of crown glass which is practically isotropic and therefore has but little dispersive power, whereas prisms made of flint glass or rock crystal are not found in the trial-case as such prisms are highly dispersive (anisotropic) and are principally used for the production of the spectrum (Fig. 49).

Achromatic Prisms.—These are seldom if ever prescribed because they are heavy, cumbersome and expensive. Such

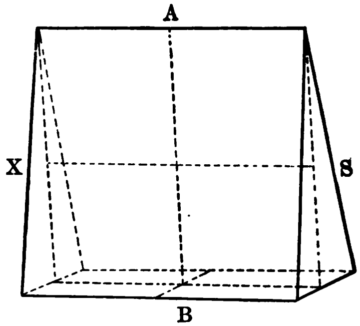

FIG. 29.—BA = Base-apex line. XS = Axis.

prisms can be made by joining or cementing together two prisms of different strength and of different index of refraction, one of flint and the other of crown glass, with the base of one to the edge of the other.

Prismatic Action.—Rays of light in a prism continue in straight lines and are not perceptibly broken up into different wave lengths (colors) so long as the glass composing the prism is isotropic. The surfaces of a prism alone deviate the rays and not the glass between the surfaces, hence the reason for speaking of the faces of a prism as refracting surfaces. Rays of light which pass through a prism are always refracted away from the edge and toward the base of the prism.

Maximum Deviation or Refraction.—By this is meant the greatest deviating power of the prism, and it is obtained when all the refraction is done at one surface, namely, (1) if an incident ray is perpendicular to the first surface of a prism, then it will pass to the second surface before it is deviated or refracted and all the refraction in this instance is done at this one surface, namely, as the ray emerges from the prism (BP, Fig. 30), (2) or if the entering (incident) ray is so bent or refracted on its entrance into the prism (AR in Fig. 30) that it becomes a perpendicular (RC) at the second surface, it will pass out of this

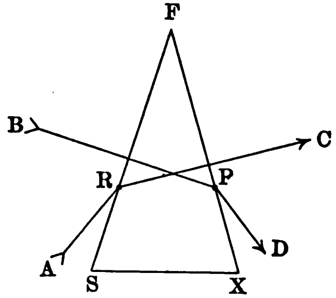

FIG. 30.—Illustrating maximum refraction or deviation. FS and FX = Surfaces. AR and BP = Incident rays. PD and RC = refracted rays.

second surface without any further deviation, all the refraction taking place at the first surface.

Minimum Deviation.—By this is meant the least effect or the smallest amount of deviating power of the prism; this takes place when the ray in the prism is parallel with the base in an equilateral prism or when it is equidistant from the edge at each surface or is deviated in an equal amount at each surface, or when the angle of incidence (IRN) is equal to the angle of emergence (VYN′) (Fig. 31). The position of the prism when this occurs is spoken of as the position of minimum deviation. Figure 31 shows the prism BAC. The ray I incident on the surface AB at R is refracted to Y and emerging at Y is again refracted

toward V. The ray RY in the prism is parallel with the base (BC); R and Y are equidistant from the edge A.

Angle of Deviation (Fig. 31).—This angle is formed by the light and is situated between the directions of the incident ray carried forward (I to D) and the emergent ray (V to I′) carried

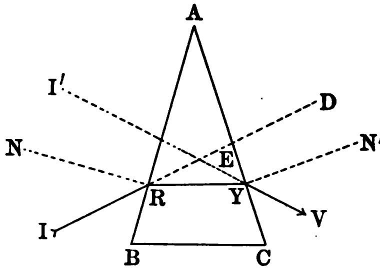

FIG. 31.—Illustrating position of minimum refraction or deviation. AB and AC = Surfaces. I = Incident ray directed toward D. RY = Course of ray in the prism and parallel to the base (BC). V = Refracted ray as if it came from I′. N and N′ = Perpendiculars or normals to surfaces AB and AC.

backward; it measures the deviation (VED). In all prisms of 10° or less the angle of deviation is slightly more than half the angle of the prism, but in prisms of more than 10° the angle of deviation is much larger.

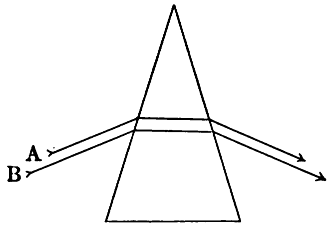

FIG. 32.—A and B, parallel rays entering the prism, are parallel as they leave the prism.

Summary.—The deviation of a ray of light passing through a prism is influenced chiefly by two factors, *i.e.*:

1. The obliquity of the refracting surfaces: The more acute the edge angle, the less the deviation; the greater the edge angle, the greater the deviation.

2. The index of refraction of the prism: The less the index of refraction, the less the angle of deviation; the greater the index of refraction, the greater the angle of deviation.

Prisms do not cause rays of light to converge or diverge:

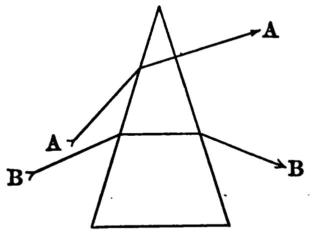

FIG. 33.—A and B are divergent as they enter and leave the prism.

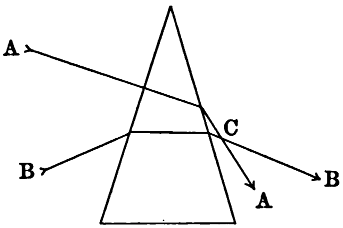

FIG. 34.—A and B are convergent as they enter and leave the prism; these rays cross at C.

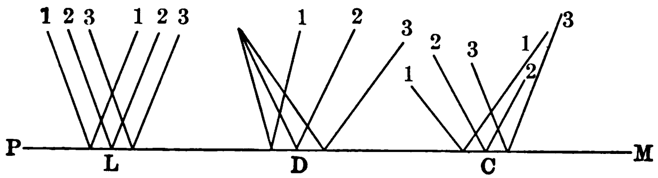

FIG. 35.—PM = Plane mirror. L = Parallel rays 1, 2, 3, reflected parallel. D = Divergent rays reflected divergently. C = Convergent rays 1, 2, 3, reflected convergently.

Rays of light that are parallel as they enter a prism are parallel as they leave it (Fig. 32). Rays of light that diverge (AB, Fig. 33) as they enter a prism will diverge as they leave it. Rays of light that converge (AB, Fig. 34) as they enter a prism

will converge when they leave it. Prisms do not form images. Prisms have no foci. A prism and a plane mirror act similarly upon rays of light, namely, if the rays of light are parallel, divergent or convergent as they fall upon a plane mirror they will be reflected in like manner (see Fig. 35).

CHAPTER III

OPTICAL EFFECT OF A PRISM

The purpose, or use, or effect of a prism is to make an object looked at through the prism appear in a different place from that which it really occupies, the prism actually producing an optical illusion. In producing this effect the object always appears displaced and in a direction always opposite to the position of the base of the prism, namely, in the direction of the edge of the prism. For instance, in Fig. 36, rays of light from X

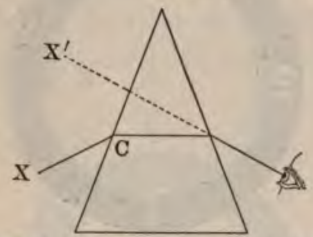

FIG. 36.—Optical effect of a prism. X appears in the position of X′.

strike the prism at C, undergo minimum refraction and falling upon the retina of the eye are projected outward in the direction from which they came to the eye, and the position of X is apparently changed to X′, away from the base and toward the edge of the prism.

Before proceeding further, the mind of the reader must be impressed with the fact that the words *edge* and *apex* as applied to a prism are synonymous terms, because only too frequently the student confuses these terms with a difference. This confusion has arisen apparently from the markings on the circular or round prisms, but by observing Fig. 25 the reader will see, as already stated in Chapter II, that the apex mark of a circular

or round prism corresponds to a point in the edge of the original square prism. If the reader will also bear in mind that the base-apex line as marked on the prism is only a guide and that there are as many imaginary base-apex lines in the prism as there are imaginary lines parallel to the one base-apex line indicated on the prism, he will fully appreciate the statement that every point in an object seen through a prism is displaced toward the edge of the prism and on a line parallel with the base-apex line. It is a very erroneous idea to get the impression in mind that because the prism is round, the object looked at

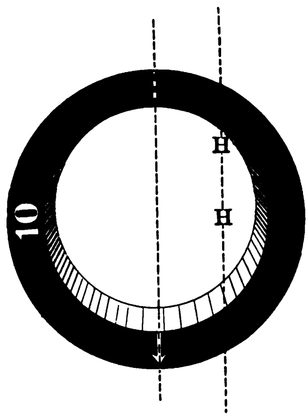

FIG. 37.—H appears displaced toward the edge of the prism and parallel to the base-apex line.

through the prism is displaced in all its parts toward the apex marking on the prism, as if it was to be crowded toward the apex of an angle. In Fig. 37 the letter H is seen through the prism to the right of the prism markings for the apex and base, and this H is displaced immediately upward on an imaginary line exactly parallel to the base-apex line and not toward the apex marking of the prism.

A straight line, at a long distance viewed through a strong prism, held base-apex at right angles to the line, appears to be curved and with the concavity toward the edge of the prism

(Fig. 38). This same straight line viewed through the prism, held with the base-apex line in the same meridian as the line,

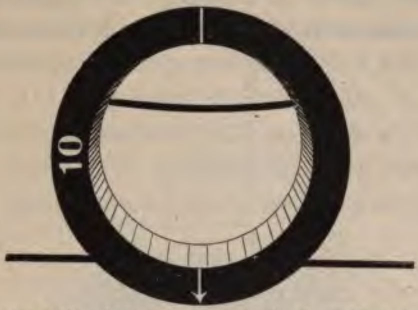

FIG. 38.—The straight line looked at through the prism appears curved, the concavity being toward the edge of the prism.

does not at first appear displaced, although it is displaced, the displaced portion simply overlying the original line and toward the edge of the prism (Fig. 39), making the line appear a trifle

FIG. 39.—The straight line seen through the prism on its base-apex line does not appear displaced.

darker and heavier. Any prism held before the eye and revolved on its plane gives an object looked at through the prism

the appearance of moving in a circle about its real position. In a right-angled triangle prism (a principal section of which is a right-angled isosceles triangle) the hypotenuse may act similar to a plane mirror (Fig. 40). Rays of light entering

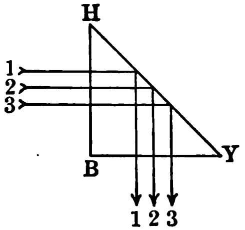

FIG. 40.—The hypotenuse HY acting as a plane mirror, producing total reflection.

such a prism at HB as normals (1, 2 and 3) fall upon the hypotenuse (HY) at an angle of incidence of 45°, and as this angle is greater than the critical angle (40° 49′) for crown glass, the

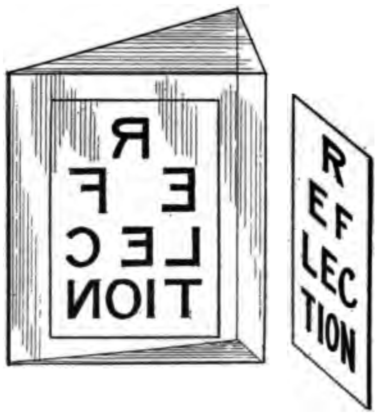

FIG. 41.—Hypotenuse acting as a plane mirror.

rays are *totally* reflected. At the same time these rays are deviated through an angle of 90°; consequently they emerge at BY as normals from the other surface of the prism. See also Fig. 41. This fact is taken advantage of in a mechanical way

by the use of these and other prisms for purposes of illumination or for deviating rays of light into dark basements, stairways, etc. (Fig. 42). Likewise prismatic action is employed in the construction of periscopes and of the lenses surrounding the light in a lighthouse (Figs. 43 and 44). "At the center of such an apparatus is a plano-convex lens, 1 ft. in diameter, the focus of which corresponds with those of the concentric lenticular rings of glass which surround it. The rings are ground and polished with great accuracy and resemble in shape an

FIG. 42.—Showing how light rays are bent by means of prism angles.

ordinary quoit and in their refraction are equivalent to a plano-convex lens with its center removed. Such lenses are so powerful that the light in a clear atmosphere may be seen at a distance of 50 or 60 miles. The apparatus is octagon in shape and provided with reflecting mirrors at those parts above and below the light which are out of the range of the lenses. The oil flame, as the radiant, is so placed that when its rays pass through the lens and prism and are reflected by the mirrors, they are deviated so as to follow the horizon very closely and do not go promiscuously skyward or immedately downward."[1]

[1] "Wonders of Optics," C. Scribner & Co.

Corneal microscopes, marine glasses, and loupes are now most ingeniously constructed with prism combinations whereby the object is greatly enlarged and given a flat surface.

Prism Aberration or Prismatic Astigmatism.—A divergent pencil of light passing through a prism and received into the

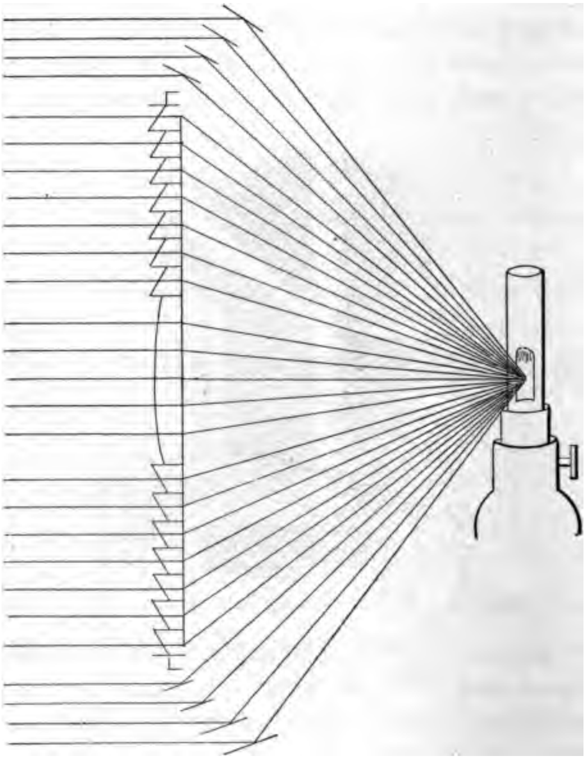

FIG. 43.—Illustrating Fresnel's lighthouse apparatus.

normal 3½-mm. round pupil of an eye is naturally projected toward the edge of the prism as just described, but it is not seen as a distinct radiant point; it appears as a point, however, with those edges blurred or indistinct which coincide with the base-apex line of the prism, while the rays of light which were refracted in the meridian corresponding to the axis of the prism

are distinct; in other words, the rays which fall upon the prism in the vertical meridian appear a trifle farther off than the rays which fall upon the prism parallel to its edge. A circle viewed through a prism appears very slightly oval on this account and with the upper and lower edges faintly blurred. This effect of a prism is spoken of as prism aberration or prismatic astigmatism, and the interval between the two focal planes is known as Sturm's interval. Very weak prisms (less than 2 centrads) have such a minute amount of aberration or astigmatism that it is really infinitesimal and often non-appreciable. It takes

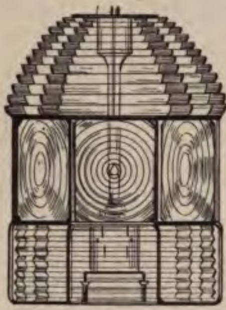

FIG. 44.—Lantern of a first-class lighthouse.

a strong prism (10 or more centrads) to demonstrate aberration, and as strong prisms are seldom prescribed this astigmatic effect need not have further consideration at this time.

Metamorphopsia.—Rotating a prism on its axis or on its base-apex line as the observer looks through it at an object, the object becomes distorted and this distortion is spoken of as metamorphopsia; for instance, holding a strong prism base downward before the eye and looking at an object (window A in Fig. 45) it naturally appears displaced upward (B in Fig. 45), then tilting the edge forward toward the object (dotted prism, same figure), thus bringing the base toward the observer's eye, gives B the appearance of being displaced still farther upward (C in Fig. 45) and at the same time the object

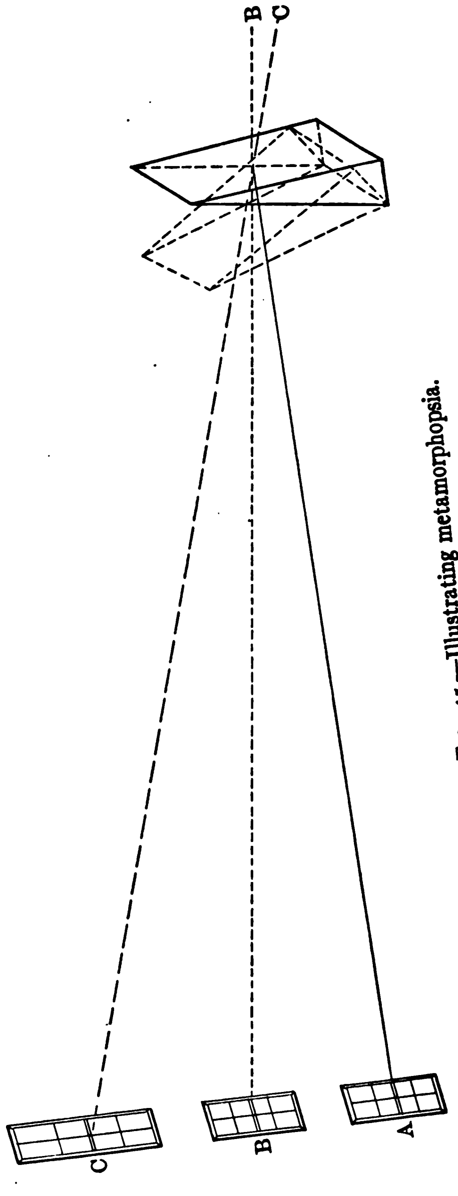

FIG. 45.—Illustrating metamorphopsia.

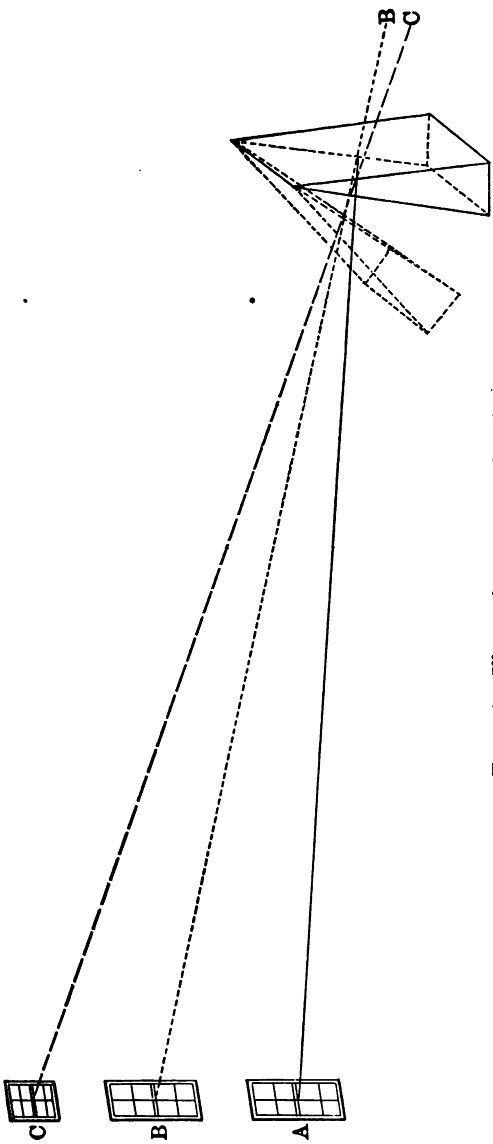

FIG. 46.—Illustrating metamorphopsia.

(window) is very much elongated (magnified) vertically, the horizontal width remaining unchanged.

Holding a strong prism base downward before the eye and tilting the base toward the object (bringing the edge toward the observer's eye) (Fig. 46) gives the displaced object (B) the

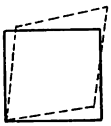

FIG. 47.

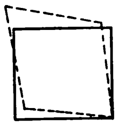

FIG. 48.

appearance of being still further displaced from B to C and very much reduced in size (minified) in the vertical meridian, and the horizontal width of the object remains unchanged. Rotating a prism to the right on its base-apex line as it is held base downward before the eye, and the eye views a

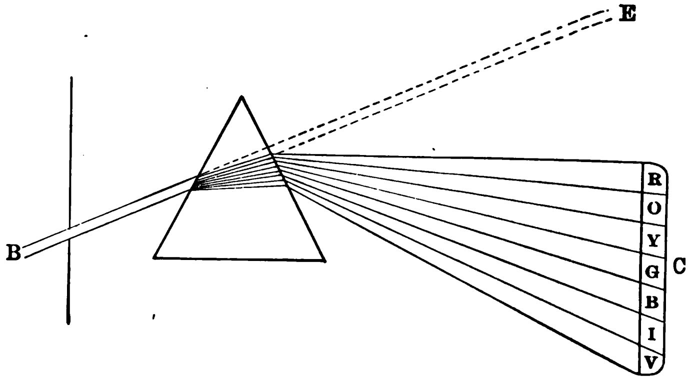

FIG. 49.—Dispersion or the production of a spectrum by a flint glass or rock crystal prism.

square through the prism, the right side of the square appears to move upward (Fig. 47), and if the prism is rotated to the left, the left side appears to move upward (Fig. 48). In each instance the square object has a distortion resembling a rhombus.

Dispersion of Light.—When a beam of solar light (B in Fig.

49) is made to pass through a prism of rock crystal or flint glass it is broken up or divided into its constituent parts and this phenomenon is spoken of as dispersion. This beam of light directed toward E if intercepted by a screen will be seen as a colored image, known as the solar spectrum at C. This image is rounded at the ends and the colors seen are red, orange, yellow, green, blue, indigo and violet in the order named—violet being the most refrangible and red the least. These colors do not have sharp lines of demarcation, but blend into each other. Dispersion plays but an infinitesimal part in ophthalmology for the reason that strong prisms are not prescribed and, furthermore, the prisms in the trial-case are of crown glass.

CHAPTER IV

PRISM NOMENCLATURE. DENNETT'S METHOD. PRENTICE'S METHOD AND NEUTRALIZING PRISMS

Numbering of Prisms.—Formerly prisms were numbered by their refracting angles or the edge angle formed between the two refracting surfaces. Such prisms were known as one degree (1°), two degrees (2°), three degrees (3°), etc. Early trial-cases had these prisms numbered in this way, sometimes as high as number twenty-four. They were often spoken of as number one, number two, number three, etc. The unit (number one) or any degree-numbered prism does not, unfortunately, signify or designate definitely the amount of deviation a ray of light will undergo in passing through such a numbered prism; the degree simply designates the inclination or angle formed by the sides of the prism. It will be noted later that this method of numbering prisms was most unsatisfactory because it did not indicate the angle of deviation which the ray of light would make when it passed through the prism. Or to state it in another way, the degree notation of prisms did not inform the surgeon just how much such a prism would deviate a ray of light when in its position of minimum deviation (Chapter II, also Fig. 31).

When referring to the strength of a prism it is always better to mention its deviating power; for instance, a number 4 prism does not convey the proper meaning except that the surfaces of such a prism have an apical angle of 4°, and therefore if we wish to say that a 4 prism will deviate a ray of light 4°, we must insert the letter "d" after the 4, which would be "4d prism." A change from this "degree" nomenclature of prisms was urged

by Dr. Edward Jackson (now of Denver, Colorado) before the Ninth International Medical Congress, and he very wisely and properly recommended that prisms be numbered or marked according to their power of deviating rays of light, and the edge angle to be ignored.

An instrument for measuring the edge angle of the prism is made by the Geneva Optical Company and called a "prism measure," but it is of no use to the oculist as it does not register the deviating power of the prism. It is an instrument, however, which the optician can use to advantage.

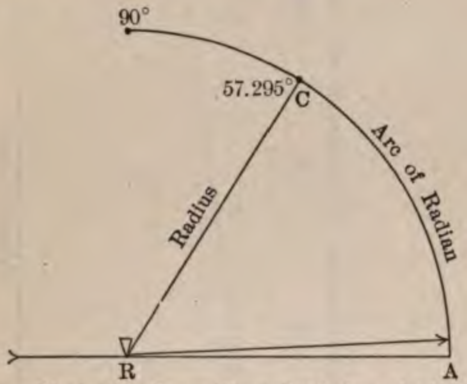

FIG. 50.—Illustrating Dennett's method of numbering prisms.

Since Dr. Jackson's recommendation for a new or exact prism nomenclature, two methods have come into use, namely, Dennett's Method and Prentice's Method.

The size of the angle of deviation produced by a ray of light passing through a prism measures the strength or the effect of the prism, and it is this angle which has given us the new nomenclatures now to be described.

Dr. Dennett's Method.—The Centrad. Abbreviated by an inverted Greek letter D (Delta) ∇. The unit of this method (one centrad) is a prism which will deviate a ray of light the one-hundredth part of the arc of the radian. This is an arc measurement and the arc of the radian always equals a little

more than 57° (57.295+°). In Fig. 50 RA and RC are radii of curvature, AC is the arc of the radian and is equal in length to either RA or RC. This arc is now divided into 100 equal parts. A prism base up at the center of curvature (R), which will deviate a ray of light just one-hundredth part of this arc, is a unit prism of 1 centrad (1^∇), and in its deviating power equals therefore the one-hundredth part of 57.295°, or 0.57295°. This unit power tells at once the deviating power of any number of centrads by simply multiplying this unit power (0.57295)

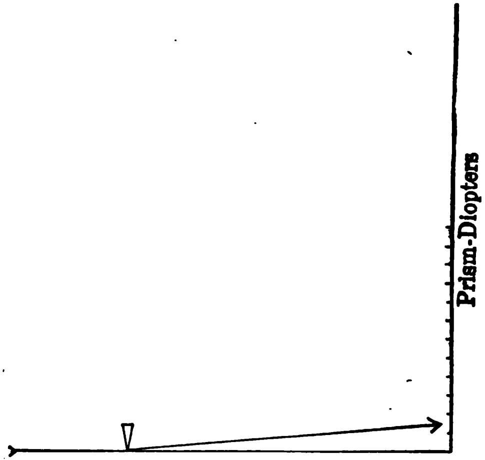

FIG. 51.—Illustrating Prentice's method of numbering prisms.

by the number of centrads in the prism; for instance, a 5-centrad prism (5^∇) will deviate a ray of light 5×0.57295 which equals 2.8647°, and a 10-centrad prism (10^∇) will deviate a ray of light 10×0.57295 which equals 5.7295°, etc.

Mr. Charles F. Prentice's Method.—Prism-diopter or prism-dioptry. Abbreviated by the Greek letter D (Delta) Δ. The unit of this method (one prism-diopter) is a prism which will deviate a ray of light just 1 cm. for each meter of distance that it travels. The prism-diopter is strictly a tangent measurement (Fig. 51). As the deviation of a prism-diopter is always

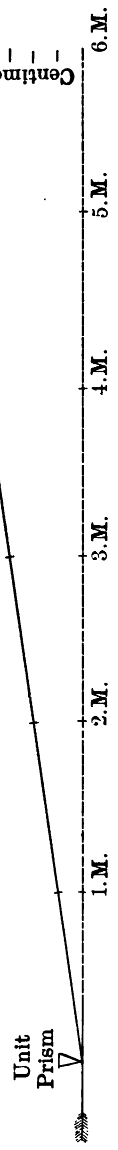

FIG. 52.—Illustrating prism power. One centimeter of deviation for each meter of distance. (Reduced size.)

1 cm. for each meter of distance then one prism-diopter will deviate a ray of light 2 cm. for 2 meters of distance, 3 cm. for 3 meters of distance, 4 cm. for 4 meters, etc. (Fig. 52).

The comparative values of centrads and prism-diopters is quite uniform up to 20, but above 20 the centrad becomes the stronger (Fig. 53). As the every-day use of prisms seldom calls for a prism stronger than 20 (centrad or prism-diopter) the

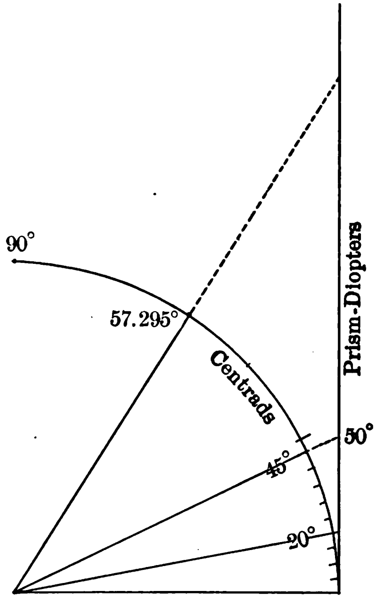

FIG. 53.—Comparing Dennett's and Prentice's methods of numbering prisms.

surgeon need not be annoyed with any distinction between the two nomenclatures until he passes to a prism stronger than 20.

The following table is self explanatory.

"The actual difference between corresponding numbers of the two scales is the difference between the tangent and the arc of the same number of hundredth-radians. The practical difference within the limits of actual use is hard to see."

"In 1891 the Ophthalmic Section of the American Medical

TABLE SHOWING THE EQUIVALENCE OF CENTRADS IN PRISM-DIOPTERS AND IN DEGREES OF THE REFRACTING ANGLE (INDEX OF REFRACTION 1.54)

Centrads	Prism-diopters	Refracting angle
1.0	1.0000	1°.00
2.0	2.0001	2°.12
3.0	3.0013	3°.18
4.0	4.0028	4°.23
5.0	5.0045	5°.28
6.0	6.0063	6°.32
7.0	7.0115	7°.35
8.0	8.0172	8°.38
9.0	9.0244	9°.39
10.0	10.033	10°.39
11.0	11.044	11°.37
12.0	12.057	12°.34
13.0	13.074	13°.29
14.0	14.092	14°.23
15.0	15.114	15°.16
16.0	16.138	16°.08
17.0	17.164	16°.98
18.0	18.196	17°.85
19.0	19.230	18°.68
20.0	20.270	19°.45
25.0	25.55	23°.43
30.0	30.934	26°.81
35.0	36.50	29°.72
40.0	42.28	32°.18
45.0	48.30	34°.20
50.0	54.514	35°.94
60.0	68.43	38°.31
70.0	84.22	39°.73
80.0	102.96	40°.29
90.0	126.01	40°.49
100.0	155.75	39°.14

Association passed a resolution recommending the adoption of the centrad unit and scale and equally with that up to 20, the prism-diopter."[1]

[1] William S. Dennett, M. D.: "System of Diseases of the Eye," Norris and Oliver, Vol. II, page 150.

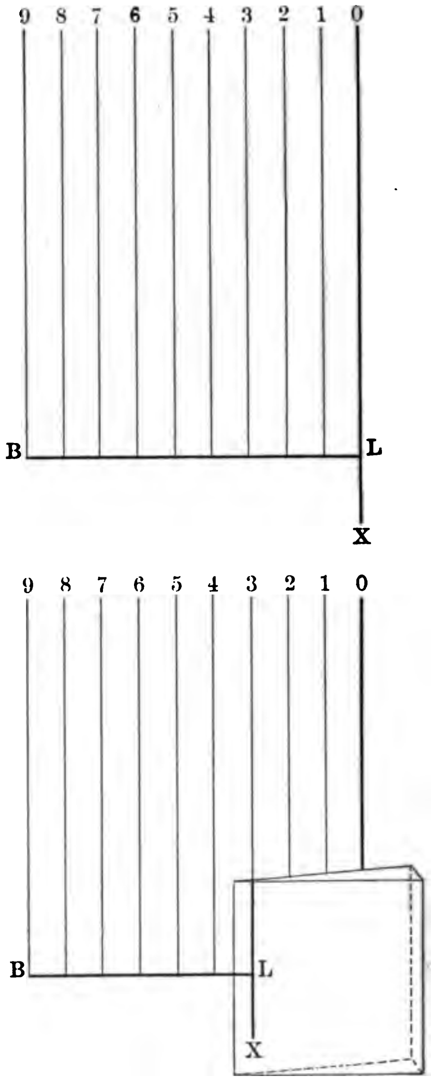

FIG. 54.—Author's method of estimating the strength of a prism.

Neutralization of Prisms.—The word neutralization as used in ophthalmology means to counteract or render inert or it may be described as antagonizing or as an opposite effect. For instance, if a ray of light passing through a prism is deviated 2 cm. at 1 meter of distance, then to neutralize this effect or antagonize this deviation it will be necessary to find a prism of equal strength and place it with its base to the apex of the

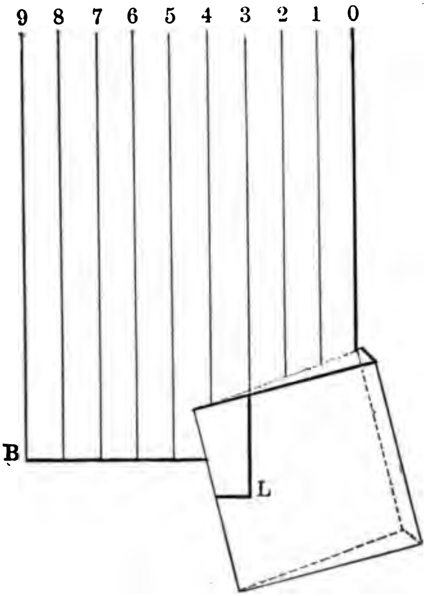

FIG. 55.

other prism, or to be able to neutralize a prism all that is necessary is to find its numeric strength. To do this, the prism to be tested must be held in its position of minimum deviation with base-apex line at right angles and over a series of numbered parallel straight lines separated by an interval of 1 cm. (or multiple or fraction thereof) and note the amount of displacement that results when the prism is held at a distance in meters (or multiple or fraction of a meter) according to the interval

between the lines. Figure 54 shows a series of vertical, parallel straight lines ½ cm. apart and numbered from 0 to 9. An X is placed at the foot of the zero line. All the parallel lines are at right angles to the black line BL. Holding a prism base to the right, meridian of 180°, at a distance of 50 cm. (½ meter) from the lines (as the lines are ½ cm. apart) and looking through the prism at X on the zero line and also at the line BL, it will be seen that the X line has been displaced to the line to the left corresponding to the number of centrads or prism-diopters in the prism which is being tested—in this instance, three. The

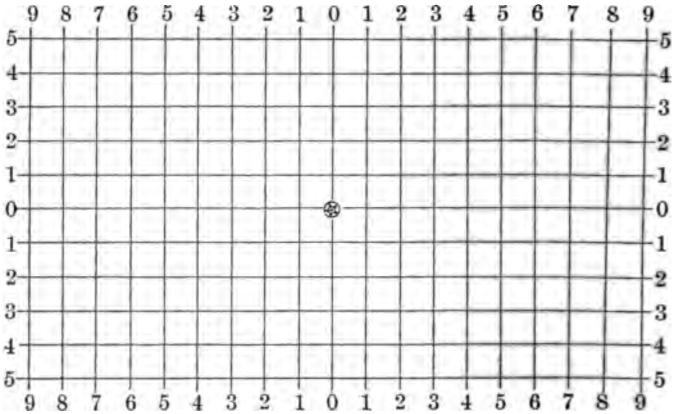

FIG. 56.—Prismometric scale of Charles F. Prentice.[1]

displaced portion of the BL line is carried forward and superimposed upon itself, otherwise it would appear out of alignment, if the prism was not held with the base-apex line corresponding to the BL line, as shown in Fig. 55. If the zero line (X) had been displaced between the lines marked 2 and 3 then the number of the prism would have been more than 2 or less than 3 centrads or prism-diopters. If it has been displaced to the line marked 5 then it would have been a 5 prism, etc. It might be just as well to remind the reader that it makes no difference at what distance his eye may be from the prism while making this

[1] Archives of Ophthalmology, Vol. XIX, No. 1, pages 64 and 68.

test, but it is of the utmost importance to hold the prism in the manner mentioned and at the exact distance in meters or fraction of a meter, corresponding to the centimeter interval between the lines. To find the strength of a prism, Mr. Prentice, who proposed the prism-diopter, recommends using a graduated card having lines upon it separated by an interval of 6 cm. and this of course must be placed at a distance of 6 meters and used as in the former test. This scale is exact and called by its author a "prismometric scale" (Fig. 56). This scale may also be used for muscle testing and is described in Chapter XVI.

A prism may be neutralized by placing another numbered prism from the trial-case in opposition to it, the base of one to the edge of the other (Fig. 57), so that in looking through the two prisms at a straight line, no matter at what distance, the straight line will continue to make an unbroken straight line. The strength of the neutralizing prism will correspond to the number of the prism being neutralized. As the prisms in the trial case occasionally get loose in their individual frames or cells, it will be well for the surgeon to test the prism in the manner described in Fig. 55 to make sure that they are properly placed. The base-apex line should coincide with the BL line and with the markings on the frame. Dr. Ziegler's prism scale (Fig. 58) is an excellent one. The directions for its use are as follows:

FIG. 57.—Neutralization of prisms.

This prism scale is to be used at a distance of ¼ meter, but a larger one for use at 2 meters is preferable as the possibility of error is much less. To use the scale close one eye, and with the other look at the scale both through the prism and over it. A comparison of these two views gives the required registration. Each field must contain either the indicator singly or the numbered gradations singly, the fields being in conjunction at the margin of the lens.

Rotate the prism until the base line seen through the prism is continuous with the base line of the scale. Always keep the plane of the prism parallel with that of the scale, and on a level

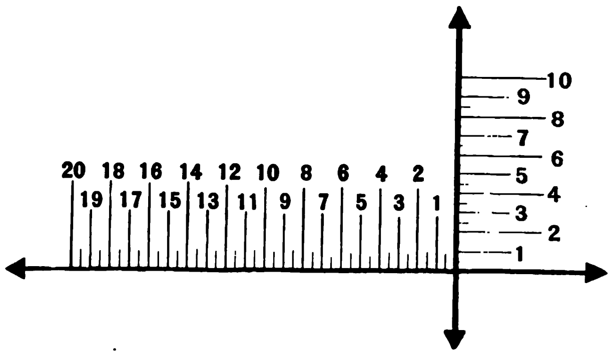

FIG. 58.—Prism scale of Dr. Lewis S. Ziegler.

with it. The index line will be displaced along the scale until the indicator stands opposite the proper numbered gradation. By moving the prism up and down along this gradation, it can be seen whether the index line accurately coincides or not.

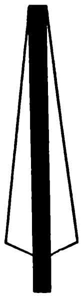

FIG. 59.—Two prisms in apposition. Base and edge of one to the base and edge of the other.

Combined Prisms.—Any two prisms of the same strength with the base of each against the edge of the other will neutralize each other and the effect will be negative.

Any two prisms of the same or different strength with the base of one to the base of the other will equal the effect of a single prism of the combined strength of the two (Fig. 59). Any two prisms, each less than 5^{v}, of the same strength held in apposition and with their base-apex lines at right angles to each other (Fig. 60) will equal or be equivalent to a single prism one or two units stronger than one of the prisms, with its base midway of the two bases. For instance, 5 prism-diopters base down meridian 45° combined with a 5 prism-diopter base down

meridian 135° will equal a 7 prism-diopter base down meridian 90°. This is a very close equivalent in effect and applies to pairs of prisms as high as 5 centrads or 5 prism-diopters, but when pairs of prisms as strong as 15 are used the effect is much greater and with 15^{∇} the effect will approximate a single 21 prism-diopter.

That the reader may fully appreciate these statements, he should make these tests for himself and in this way become familiar with the prism effects or equivalents. The following description will also be of assistance:

FIG. 60.—Two prisms of the same strength superimposed. One base down meridian 45° and the other base down meridian 135°.

FIG. 61.

Figure 61 shows a single 8 prism-diopter held about 10 in. away from and directly over the word "Prism." (Both eyes of the observer must be kept open to make this test.) The base-apex line is on meridian 45° and base downward. The word "Prism" now seen through the prism appears displaced upward to the right on the base-apex line, on meridian 45°. Likewise Fig. 62 shows another prism of same strength held in the same manner over another word "Prism" and the base-apex line of the prism downward on meridian 135°. It produces a similar amount of displacement of the word "Prism," upward and to the left on meridian 135°. If these two prisms are now super-

imposed with their base-apex lines in their respective positions (45° and 135°) as shown in Fig. 60, and the word "Prism" as also shown in Fig. 60, is now looked at through this combination, the word "Prism" will appear displaced upward on meridian 90° and the effect thus produced is equivalent to a single 11 prism base-down in meridian 90°, Fig. 63.

As just stated and illustrated (Fig. 57), any two prisms of the same strength with the base of one to the apex of the other, neutralize each other and the effect is negative, but if these two prisms still held in opposition are now revolved in opposite directions at an equal rate of speed, the effect produced is that

FIG. 62.

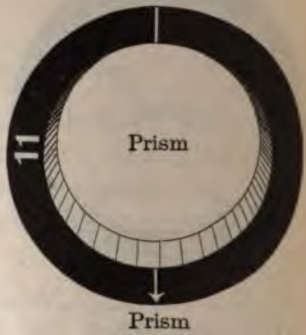

FIG. 63.

of a prism gradually growing stronger and stronger in its effect until the bases of the two prisms become superimposed and the resulting effect will be the combined strength of the two prisms (Fig. 59).

At first thought the student will naturally imagine that such a mechanism (Fig. 60) must produce two images (diplopia) of any object looked at, but the error of this supposition will be dispelled by reference to Fig. 60 and by making the tests for himself. Sir John Herschel was the first to show the effect of combining two prisms and by rotating them in opposite directions to obtain the effect of a single prism of increasing strength up to the combined value of the two.

Crété of Paris was the first to bring forth an instrument which gave practical use to two superimposed prisms. It is called "Crété's Prism" or the "Prisme mobile" (see Fig. 64). These two prisms are mounted in a circular cell with a straight handle. This handle contains a slot through which travels a movable button adjusted to the prisms so that on pushing the button upward or downward the prisms are made to revolve in opposite directions at an equal rate of speed. The figures on the handle opposite the gauge record the strength of the prism thus produced.

FIG. 64.—Front view of the revolving prisms as arranged by Crété.

The handle of the "Crété prism" and also the position of its degree markings interfere with its usefulness and make it cumbersome for every-day practice; in fact the instrument is rather obsolete for these reasons. The most adaptable form of Crété's prism which does away with the handle is that of Dr. S. D. Risley, known as the "Rotary prism," Fig. 65. This apparatus which may be used in the trial-frame is composed of two superimposed prisms of 15 prism-diopters or 15 centrads each, and mounted in a cell of the size of the trial-lens. By means of a milled edged screw these prisms are made to revolve so that in position of zero they neutralize each other, and when revolved over each other the prism strength gradually increases until the bases of the two prisms superimpose, equalling (15+15) 30 centrads. The prism strength is indicated by a pointer directed to the scale on the periphery of the cell. "Rotary prisms" are made in two

strengths, one contains two 10 prisms and the other, as just described, two 15 prisms. See chapter on Muscle Testing.

Jackson's triple prism (Fig. 66) is very similar to the Crété or Risley prism. It contains three prisms, as its name implies; one of these is stationary and the other two revolve.

Uses of Prisms.—1. To detect malingerers who profess monocular blindness so as to obtain damages for supposed injuries, or who wish to escape war service, or those cases of hysteric blindness wishing to create sympathy. This test or use of a prism is known as the diplopia test, and is practised as follows: A 7 P. D., base up or down, with a blank are placed in the trial-frame corresponding to the "blind" eye; nothing is placed in

FIG. 65.

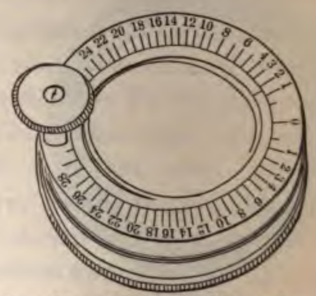

FIG. 66.—Jackson's triple prism.

front of the seeing eye; the trial-frame, thus armed (without the patient seeing what is being done), is placed on the patient's face and he is instructed to read the card of test-letters on the wall across the room. While he is thus busy reading, and purposely contradicted by the surgeon, so as to get his mind from his condition, the surgeon suddenly removes the blank from the "blind" eye. The patient exclaiming that he sees two cards and two of all the letters proves the deception.

2. Occasionally, to counteract the effects of strabismus, or diplopia due to a paralysis of one or more of the extra-ocular muscles. For example: A patient looking at a point of light focused on the macula (M) of the left eye (L), the right eye

being turned in toward the nose, receives the rays upon the retina to the nasal side of the macula, and hence projects the rays outward to the right, giving a false image to the right side; a prism of sufficient strength is then placed with its base toward the temple (base out) over the right eye, so that the rays from the light may fall upon the macula (M), and the diplopia will be corrected (see Fig. 67).

3. To test the strength of the extra-ocular muscles. A patient looking with both eyes at a distant point of light is made to see

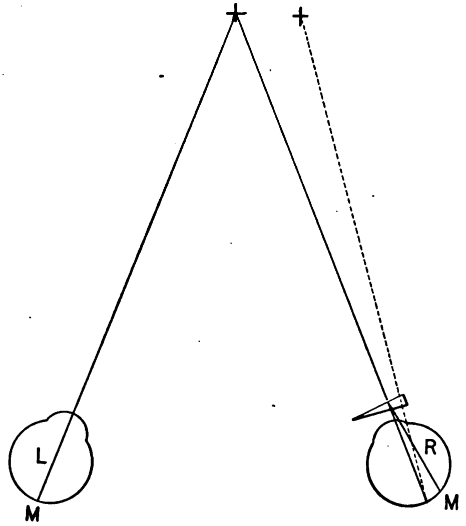

FIG. 67.

one light just above another by placing a 3 P. D., base down or up, before either eye, and if a 2½ P. D. did not produce diplopia when similarly placed, the strength of his vertical recti is then represented by 2½ P. D. The strength of the prism placed base in which, if increased, would produce diplopia is the strength of the externi; and the strength of the prism or prisms placed base outward which, if increased, would produce diplopia is the strength of the interni.

4. For exercise of weak muscles see page 272.

CHAPTER V

LENSES

Lenses.—A lens is a portion of transparent substance (usually of glass) having one or both surfaces curved. There are two kinds of lenses—spheric and cylindric.

Spheric Lenses.—Abbreviated S. or sph., or sph. D. Spheric lenses are so named because their curved surfaces are sections of spheres. A spheric lens is one which refracts rays of light equally in all meridians or planes. Spheric lenses are of two kinds—convex and concave.

FIG. 68.

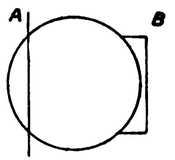

FIG. 69.

FIG. 70.

A convex spheric lens is thick at the center and thin at the edge (Figs. 68, 70, 72). The following are synonymous terms for a convex lens: (1) Plus; (2) positive; (3) collective; (4) magnifying. A convex lens is denoted by the sign of plus (+).

Varieties or Kinds of Convex Lenses.—

1. *Planoconvex*, meaning one surface flat and the other convex (see Fig. 68). It is a section of a sphere (see Fig. 69, A).

2. *Biconvex*, also called convexoconvex or bispheric, for the reason that it is equal to two planoconvex lenses with their plane surfaces together (Fig. 70). It equals a section of two spheres (see CX, Fig. 71).

3. *Concavoconvex.* This lens has one surface concave and the other convex, the convex surface having the shorter radius of curvature (Figs. 72 and 73, M). This lens like that figured in 71 is also equal to a section of two spheres, but one smaller than the other, shown at M in Fig. 73, the smaller spheric curve giving the convex curve and the larger spheric curve giving the concave curve. The following are synonymous terms for a concavoconvex lens: (1) Periscopic; (2) convex meniscus; (3) converging meniscus (meniscus meaning a small moon) (see Fig. 72). A periscopic and meniscus lens enlarges the field of vision, and is of especial service for presbyopia.

A convex periscopic lens (Fig. 72) is always made with the the concavity of minus 1.25; for instance, a plus 3 peri-

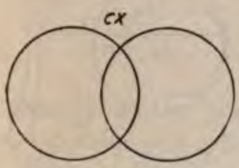

FIG. 71.

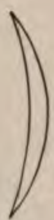

FIG. 72.

FIG. 73.

scopic would have a convex surface of plus 4.25 sphere, and the concave surface would be minus 1.25, equaling therefore plus 3.

A convex meniscus, however, is not exactly the same as a convex periscopic, as the meniscus always has a concave surface of minus 6; for example, a plus 3 meniscus would have a concavity of minus 6, and the convex surface of plus 9. Menisci lenses are very seldom prescribed.

A Concave Spheric Lens.—Such a lens is thick at the edge and thin at the center (Figs. 74, 76, 78). The following are synonymous terms for a concave lens: (1) Minus; (2) negative; (3) dispersive; (4) minifying. A concave lens is denoted by the sign of minus (—).

Varieties or Kinds of Concave Lenses.—

1. *Planoconcave*, meaning one surface flat and the other concave (Fig. 74, and B in 69).

2. *Biconcave*, also called concavoconcave or biconcave spheric, for the reason that it is equal to two planoconcave lenses with their plane surfaces together (Figs. 75 and 76). It also equals a section of two hollow spheres.

3. *Convexoconcave*. This lens has one surface convex and the other concave, the concave surface having the shorter radius of curvature (Figs. 77, M, and 78). The following are synonymous terms for a concavoconvex lens: (1) Concave meniscus; (2) diverging meniscus; (3) periscopic.


FIG. 74.

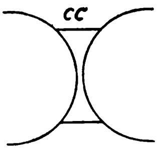

FIG. 75.


FIG. 76.

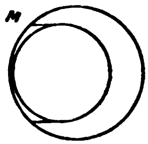

FIG. 77.


FIG. 78.

A concave periscopic lens (Fig. 78) is always made with the convexity of plus 1.25; for instance, a minus 3 periscopic would have a convex surface of plus 1.25 sphere, and the concave surface would be minus 4.25, equaling therefore minus 3.

A concave meniscus is the reverse of the convex meniscus, in that the convex meniscus has a concave surface of minus 6, the concave meniscus has a convex surface of plus 6. For example, a concave meniscus of minus 3 has a convex surface of plus 6, and a concave surface of minus 9. This kind of lens is seldom ordered.

A spheric lens may be considered as made up of a series of prisms which gradually increase in strength from the center to the periphery, no matter whether the lens be concave or convex.

In the convex sphere the bases of the prisms are toward the

center of the lens, whereas in the concave the bases of the prisms are toward the edge (see Figs. 79, 80).

Knowing that a prism refracts rays of light toward its base, it may be stated as a rule that every lens bends rays of light

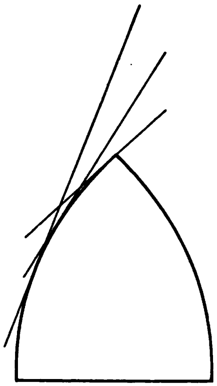

FIG. 79.

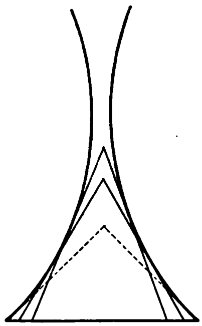

FIG. 80.

more sharply as the periphery is approached; *i.e.*, at the periphery the strongest prismatic effect takes place.

Lens Action.—As a ray of light will travel in a straight line as long as it continues to form right angles with surfaces, then the

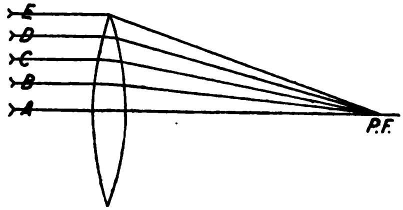

FIG. 81.

ray A in Fig. 81 passes through the biconvex lens unrefracted, or without any deviation from its course whatsoever, for at its points of entrance and emergence the surfaces of the lens are plane to each other. This ray is called the axial ray, and the line joining the centers of curvature of the two surfaces is called

the principal axis. The axis of a planoconvex or planoconcave lens is the line drawn through the center of curvature perpendicular to the plane surface.

The ray B in Fig. 81, though parallel to the ray A, forms a small angle of incidence, and must, therefore, be refracted toward the perpendicular to the surfaces of the lens and, passing through the lens, will meet the axial ray at P.F. The rays C, D, and E, also parallel to A and B, form progressively larger angles with the surface of the lens, and finally meet the axial ray at P.F. It will be seen at once that the rays all meet at P.F., showing the progressively stronger prismatic action that takes place as the periphery of the lens is approached.

In Fig. 82 we have similar rays, A, B, C, D, and E, passing

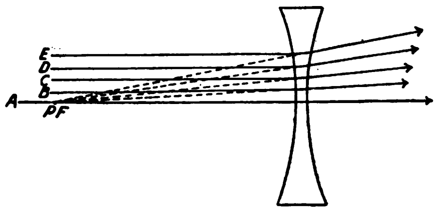

FIG. 82.

through a concave lens. The axial ray A passes through the centers of curvature unrefracted, but the rays B, C, D, and E are progressively refracted more and more as the periphery is approached. The ray E in each instance is refracted the most.

The action of a convex lens is similar to that of a concave mirror, and the action of a concave lens is similar to that of a convex mirror.

Principal Focus.—The principal focus of a lens may be defined (1) as the point where parallel rays, after refraction, come together on the axial ray; or (2) as the shortest focus; or (3) as the focal point for parallel rays.

Focal Length.—This is the distance measured from the optic center to the principal focus. The principal focus of an equally biconvex or biconcave lens of crown glass is situated at about the

center of curvature for either surface of the lens. A lens has two principal foci, an anterior and a posterior, according to the direction from which the parallel rays come, or as to which radius of curvature is referred to (see page 99). Figure 81 shows parallel rays, B, C, D, and E, passing through a convex lens and coming to a focus on the axial ray (A) at P.F.; and as the path of a ray passing from one point to another is the same, no matter what its direction, then if a point of light be placed at the principal focus of a lens its rays will be parallel after passing back through the lens. This is equivalent to what takes place in the standard or emmetropic eye; an eye, in other words, which has its fovea situated just at the principal focus of its dioptric media. Such an eye in a state of rest receives parallel rays exactly at a focus upon its fovea, and therefore is in a condition to project parallel rays outward.

Conjugate Foci.—Conjugate meaning "yoked together." The point from which rays of light diverge (called the radiant)

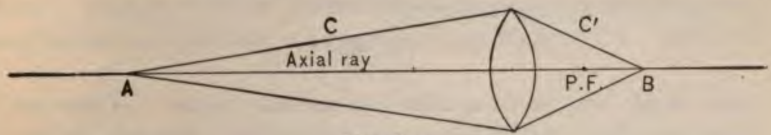

FIG. 83.

and the point to which they converge (called the focus) are conjugate foci or points. For instance, in Fig. 83 the rays diverging from A and passing through the lens converge to the point B; then the points A and B are conjugate foci. They are interchangeable, for if rays diverged from B they would follow the same path back again and meet at A. The path of the ray CC′ is the same whether it passes from A to B or from B to A: there is no difference. It is by the affinity of these points for each other, with respect to their positions, that they are called conjugate.

The conjugate foci are equal when the point of divergence is at twice the distance of the principal focus. The equivalent to

conjugate foci is found in the long or myopic eye; an eye, in other words, which has its fovea situated farther back than the principal focus of its dioptric media, the result being that rays of light from the fovea of such an eye would be projected convergently after passing out of the eye, and would meet at some point inside of infinity. In other words, only those rays which have diverged from some point inside of 6 meters will focus upon the fovea of this long eye. The fovea of the myopic eye represents a conjugate focus. A myopic eye is in a condition to receive divergent rays of light at a focus on its retina and to emit convergent rays.

Ordinary Foci.—When rays of light diverge from some point *inside* of infinity (6 meters) they will be brought to a focus at some point on the other side of a convex lens, ***beyond*** its principal focus; this point is called an ordinary focus. A lens may have many foci, but only two principal foci. The farther away from a lens the divergent rays proceed, the nearer to the principal focus on the other side of the lens will they converge. As the divergent rays are brought closer to the lens they reach a point where they will not focus, but will pass parallel after refraction. This point is the principal focus (see Fig. 84). A lens, therefore, has as many foci as there are imaginary points on the axial ray between the principal focus and infinity.

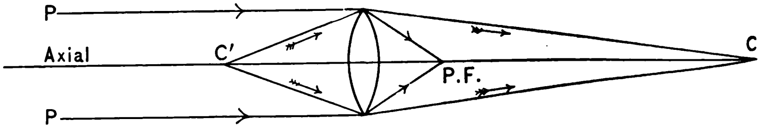

FIG. 84.

When rays of light diverge from some point closer to a lens than its principal focus, they do not converge, but, after refraction, continue divergently; their focus now is negative or virtual, and is found by projecting these divergent rays back upon themselves to a point on the same side of the lens from which they appeared to come (see Fig. 85).

This is the equivalent of what takes place in a short or hyperopic eye, an eye which has its macula closer to its dioptric media than its principal focus. In a state of rest the fovea of such an eye would project outward divergent rays, and would be in a position to receive only convergent rays of light at a focus upon its fovea.

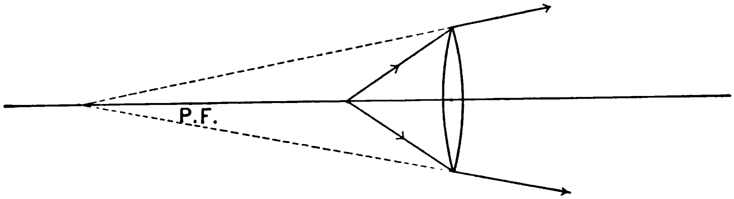

FIG. 85.

Secondary Axes.—In the study of the direction of a ray of light passing through a dense medium with plane surfaces, it was found that it underwent lateral displacement (see Fig. 13), and so in lenses there is a place where rays undergo lateral displacement. Figure 86 shows a convex lens of considerable thickness, and on each side is drawn a radius of curvature (CC). The ray

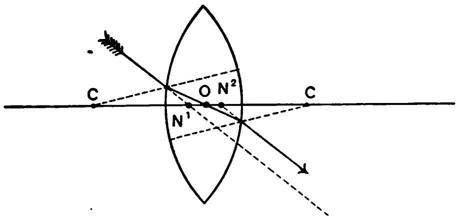

FIG. 86.

indicated by the arrow passed through the two surfaces has undergone lateral displacement, but continues in its original direction; such rays are called secondary rays or axes. The incident ray is projected toward N^1 in the lens on the axial ray, and the emergent ray, if projected backward, would meet the axial ray at N^2. These points on the axial ray are such that a ray directed to one before refraction is directed to the other

after refraction. The points N^1 and N^2 are spoken of as nodal points. Every lens, therefore, has two nodal points, but in thin lenses the deviation of the secondary rays is so slight that, for all practical purposes, only one nodal point is recognized. It is spoken of as the optic center. When writing prescriptions for glasses, this point of having the lenses or glasses made as thin as possible must be borne in mind.

Optic Center.—This term is used synonymously with nodal point, and is the point where the secondary rays (*s.a.* in Fig. 87) cross the axial ray. It is not always the geometric center. Rays of light crossing the optic center in thin lenses are not considered as undergoing refraction (see Fig. 87).

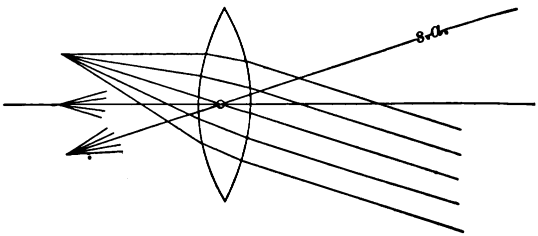

FIG. 87.

Action of Concave Lenses.—Rays of light passing through a concave lens, no matter from what distance, are always refracted divergently, and its focus is therefore always negative or virtual, and is found by projecting these divergent rays backward in the direction from which they appear to come until they meet at a point on the axial ray. The principal focus and conjugate foci of concave lenses are found in the same way as in convex lenses (see Figs. 82, 90).

Images Formed by Lenses.—An image formed by a lens is composed of foci, each one of which corresponds to a point in the object. Images are of two kinds—real and virtual.

A Real Image.—This is an image formed by the actual meeting of rays; such images can always be projected onto a screen.

A Virtual Image.—This is one that is formed by the prolongation backward of rays of light to a point.

To find the position and size of an image it is necessary to obtain the conjugate foci of the extremes of the object, as the image of an object is equal to the sum of its intermediate points. Only two rays are required for this purpose, one parallel to the axial ray and one secondary ray passing through the optic center; the image of the extreme point of the object will be located at the point of intersection of these rays. In Fig. 88, AB is an object in front of a convex lens. o is the optic center and P.F. the principal focus. A ray drawn from A parallel to the axial ray, and a secondary ray from the same point drawn through the optic center o, will give at their point of intersection the conjugate focus of the luminous point A, which will be at A′.

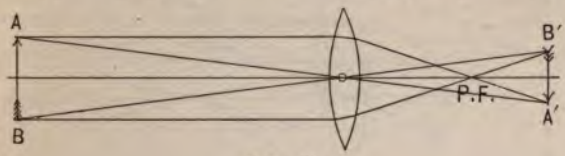

FIG. 88.

In the same way the conjugate focus of B and points intermediate in the object may be obtained. A′B′ is a real inverted image of AB; the size of the image of AB depends upon the distance of the object from the lens. The relative sizes of image and object are as their respective distances from the optic center of the lens. For example, if an object 10 mm. high is 3 meters (3000 mm.) from the optic center of a lens and its image is 60 mm. from the lens, the image will be $^{60}/_{3000}$ or $^{1}/_{50}$ of the size of the object; that is, the image will be $^{1}/_{50}$ of 10 mm. (the height of the object)—namely, $^{1}/_{5}$ mm. high.

As conjugate foci are interchangeable, then in Fig. 88 if A′B′ was the object the image AB would be the image of A′B′ and, therefore, larger than the object.

Three facts should be borne in mind in the study of real images formed by a convex lens:

1. The object and image are interchangeable.

2. The object and the real image are on opposite sides of the lens, and,

3. As the rays which pass through the optic center cross each other at this point, the real image must be inverted.

Rays of light from an object situated at the distance of the principal focus would proceed parallel after refraction, and no image of the object would be obtained.

If an object is situated just beyond the principal focus, then the image would be larger than the object, real and inverted (see Fig. 88, reversing image for object).

If an object is situated at twice the distance of the principal focus, then its image would be of the same size, real, inverted,

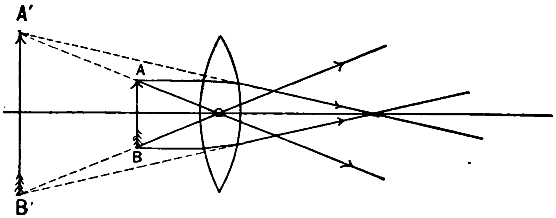

FIG. 89.

and at a corresponding distance, as these conjugate foci are equal.

If an object is situated at a greater distance than twice the principal focus, and nearer than infinity, its image will be real, inverted, and smaller than the object.

Rays of light from an object situated closer to a lens than its principal focus would be divergent after refraction, and could only meet by being projected backward; the image would, therefore, be larger than the object, erect, and virtual. Such an image is only seen by looking through the lens; the lens in this instance being a magnifying glass (Fig. 89).

Images Formed by Concave Lenses.—These images are always erect, virtual, and smaller than the object (see Fig. 90).

A concave lens is, therefore, a minifying lens. Parallel rays from the extremes of the object AR form the divergent rays A′ and R′ after refraction. Secondary rays pass through the optic center o unrefracted, A″ and R″. At the points of intersection where these rays meet after being projected backward, the image of AR is found, erect, virtual, and diminished in size. This image is only seen by looking through the lens.

Numeration of Lenses.—Formerly, lenses were numbered according to their radii of curvature in Paris inches (27.07 mm.). The unit was a lens that focused parallel rays of light at

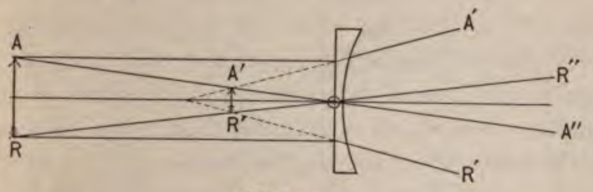

FIG. 90.

the distance of one English inch (25.4 mm.) from its optic center.

As lenses for purposes of refraction were never as strong as the unit, they were numbered by fractions, thus showing their relative strength as compared to this unit; for instance, a lens that was one-fourth the strength of the unit was expressed by the fraction $\frac{1}{4}$, or a lens that was one-sixteenth the strength of the unit was expressed as $\frac{1}{16}$, etc., the denominator of the fraction indicating the focal length of the lens in Paris inches.

There are three objections to this nomenclature: (1) The difference in length of the inch in different countries; (2) the inconvenience of adding two or more lenses numbered in fractions with different denominators—$\frac{1}{44} + \frac{1}{36} + \frac{1}{42}$; (3) the want of uniform intervals between numbers.

In the new nomenclature, and the one that is now quite uni-

versal, known as the metric or dioptric system (diopter, abbreviated D.), a lens has been taken as the unit which has its principal focus at 1 meter distance (39.37 English in.), commonly recognized as 40 in.

Lenses in the dioptric system are numbered according to their refractive power and not according to their radii of curvature. The strength or refractive power of a dioptric lens is, therefore, the inverse of its focal distance. To find the focal distance of any dioptric lens in inches or centimeters, the number of diopters expressed must be divided into the unit of 40 in. or 100 cm. For example, a 2 D. lens has a focal distance of 40 ÷ 2 equals 20 in.; or 100 cm. ÷ 2 equals 50 cm. A + 4D. has a focal distance of 40 ÷ 4, equaling 10 in., or 100 ÷ 4, equaling 25 cm. Lenses that have a refractive power less than the unit are not expressed in the form of fractions, but in the form of decimals; for example, a lens which is only one-fourth, one-half, or three-fourths the strength of the unit is written 0.25, 0.50, 0.75, respectively, and their focal distances are found in the same way as in dealing with units: 0.25 D. has a focal distance of 40 ÷ 0.25 or 100 ÷ 0.25, equaling 160 in. or 400 cm.; 0.50 D. has a focal length of 40 ÷ 0.50 or 100 ÷ 0.50, equaling 80 in. or 200 cm.; 0.75 D. has a focal length of 40 ÷ 0.75 or 100 ÷ 0.75 equaling 53 in. or 133 cm. Unfortunately, 0.25 D., 0.50 D., and 0.75 D. are frequently spoken of as twenty-five, fifty, and seventy-five, which occasionally leads to confusion in the consideration of the strength and focal distance. The student should learn as soon as possible to change the old nomenclature into the new, as he will have to make these changes in reading other textbooks.

To change the old "focal length" or inch system of numbering lenses into diopters, divide the unit (40 in.) by the denominator of the fraction, and the result will be an approximation in diopters; for example, $\frac{1}{10}$ equals $\frac{40}{10}$ or 4 D., $\frac{1}{20}$ equals $\frac{40}{20}$ or 2 D. The following table, from Landolt, gives the equivalents in the old and new systems:

Old system				New system			
I No. of the slens, old ystem	II Focal distance in English inches	III Focal distance in milli-meters	IV Equiva-lent in diopters	V No. of the lens, new system	VI Focal distance in milli-meters	VII Focal distance in English inches	VIII No. corre-sponding of the O system
72	67.9	1724	0.58	0.25	4000	157.48	166.94
60	56.6	1437	0.695	0.5	2000	78.74	83.46
48	45.3	1150	0.87	0.75	1333	52.5	55.63
42	39.6	1005	0.99	1.0	1000	39.37	41.73
36	34.0	863	1.16	1.25	800	31.5	33.9
30	28.3	718	1.39	1.5	666	26.22	27.79
24	22.6	574	1.74	1.75	571	22.48	23.83
20	18.8	477	2.09	2.0	500	19.69	20.87
18	17.0	431	2.31	2.25	444	17.48	18.53
16	15.0	381	2.6	2.5	400	15.75	16.69
15	14.1	358	2.79	3.0	333	13.17	13.9
14	13.2	335	2.98	3.5	286	11.26	11.94
13	12.2	132	3.20	4.0	250	9.84	10.43
12	11.2	287	3.48	4.5	222	8.74	9.26
11	10.3	261	3.82	5.0	200	7.87	8.35
10	9.4	239	4.18	5.5	182	7.16	7.6
9	8.5	216	4.63	6.0	166	6.54	6.93
8	7.5	190	5.25	7.0	143	5.63	5.97
7	6.6	167	5.96	8.0	125	4.92	5.22
6½	6.13	155	6.42	9.0	111	4.37	4.63
6	5.6	142	7.0	10.0	100	3.94	4.17
5½	5.2	132	7.57	11.0	91	3.58	3.8
5	4.7	119	8.4	12.0	83	3.27	3.46
4½	4.2	106	9.4	13.0	77	3.03	3.21
4	3.8	96	10.4	14.0	71	2.8	2.96
3½	3.3	84	11.9	15.0	67	2.64	2.8
3¼	3.1	79	12.7	16.0	62	2.44	2.59
3	2.8	71	14.0	17.0	59	2.32	2.46
2¾	2.36	66	15.1	18.0	55	2.17	2.29
2½	2.6	60	17.7	20.0	50	1.97	2.09
2¼	2.1	53	18.7				
2	1.88	48	20.94				

Cylindric Lenses.—Abbreviated cyl., c, or C., or C. D. A cylindric lens, usually called a "cylinder," receives its name from being a segment of a cylinder parallel to its axis (see Fig.

91). Occasionally cylinders are made with both surfaces curved, and are then equivalent to two planocylinders with their plane surfaces together. *A cylinder may be defined as a lens which refracts rays of light opposite to its axis.* This definition should be carefully borne in mind in contradistinction to a

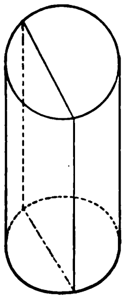

FIG. 91.

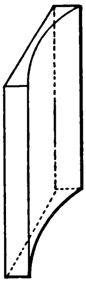

FIG. 92.

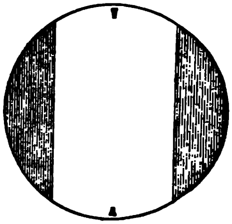

FIG. 93.

spheric lens, which refracts rays of light equally in all meridians. A cylindric lens has no one common focus or focal point, but a line of foci, which is parallel to its axis.

Axis of a Cylinder.—That dimension of a cylindric lens which is parallel to the axis of the original cylinder of which it is a

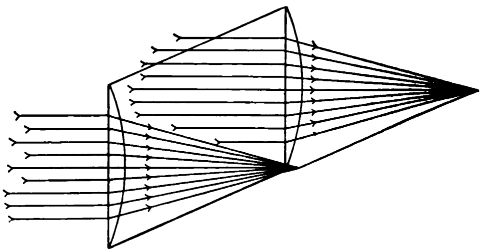

FIG. 94.

part is spoken of as the axis, and is indicated on the lens of the trial-case by a short diamond scratch at its periphery, or by having a small portion of its surface corresponding to the axis ground at the edges, or it may be marked in both ways (see

Fig. 93). Cylinders are of two kinds—convex and concave (Figs. 91 and 92).

Cylinder Action.—A convex cylinder converges parallel rays of light so that after refraction they are brought into a straight line which corresponds to the axis of the cylinder; for instance, a +5 cyl. will converge parallel rays so that they come together in a straight line at the distance of 8 in., or 20 cm., and this straight line will be parallel to the axis of the cylinder (Fig. 94).

A concave cylinder diverges rays of light opposite to its axis, as if they had diverged from a straight line on the opposite side of the lens (Fig. 95).

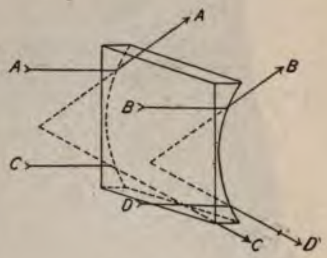

FIG. 95.

Spherocylinders.—A spherocylinder is a combination of a sphere and a cylinder, and is therefore a lens which has one surface ground with a spheric curve and the other surface cylindric. A spherocylindric lens is also spoken of as an astigmatic lens (see Fig. 174). A spherocylindric lens is one which has two focal planes. Spherocylinders have different curves: the spheric curve may be convex, with the cylindric surface convex; or the spheric surface may be concave, with the cylindric surface concave; or the spheric surface may be convex, with the cylindric surface concave; or the spheric surface may be concave, with the cylindric surface convex.

The Trial-case (see Fig. 96).—This case contains pairs of plus and minus spheres and pairs of plus and minus cylinders; also prisms numbered from ¼ or ½ to 20 Δ. The spheres are numbered in intervals of 0.12 up to 2 S.; and from 2 S. up to 5 S. the interval is 0.25 S.; and from 5 S. to 8 S. the interval is 0.50 S.; and from 8 S. to 22 S. the interval is 1 S. The cylinders have similar intervals, but seldom go higher than 6 or 8 cyl.

The trial-case also contains a trial-frame, which is used to place lenses in front of the patient's eyes (see Fig. 97). The

eye-pieces of such a frame are numbered on the periphery in degrees of half a circle, so that the axis of a cylinder may be seen during refraction. The left of the horizontal line on each eye-piece is recognized as the starting-place, or zero (0), and the degrees are marked from left to right on the *lower half*, counting around to the horizontal meridian, which at the right hand is numbered 180; this horizontal meridian is, therefore, spoken of as horizontal, zero (0), or 180°. The meridian mid-

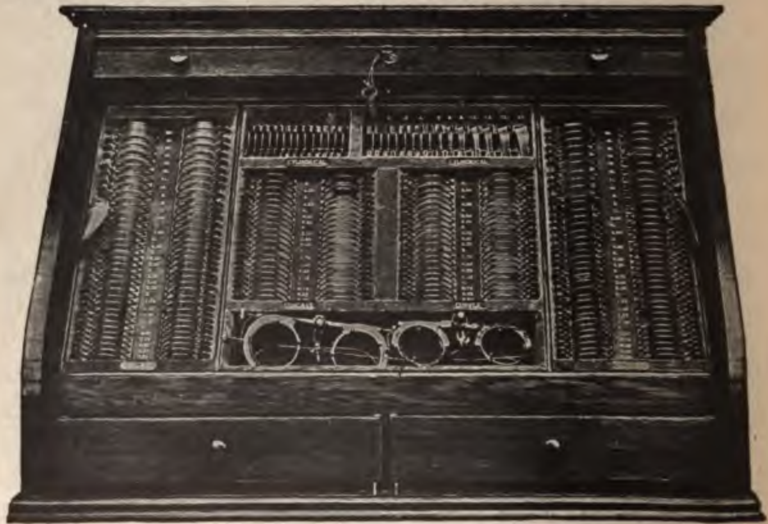

FIG. 96.

way between zero and 180 is spoken of as vertical, or 90°. Or the right of the horizontal line on each eye-piece may be recognized as the starting-point also or zero (0) and the degrees marked from right to left on the upper half, counting around to the horizontal or 180°. Or, as in Fig. 98, the degrees may be marked partly on the upper half and lower also.

In some countries the meridians are differently numbered (see Fig. 99); for example, the vertical meridian is called zero, and the degrees are marked on each side of zero up to 90°. Only

the upper half of the eye-piece is thus numbered, so that when a cylinder has the upper end of its axis inclined toward the nose

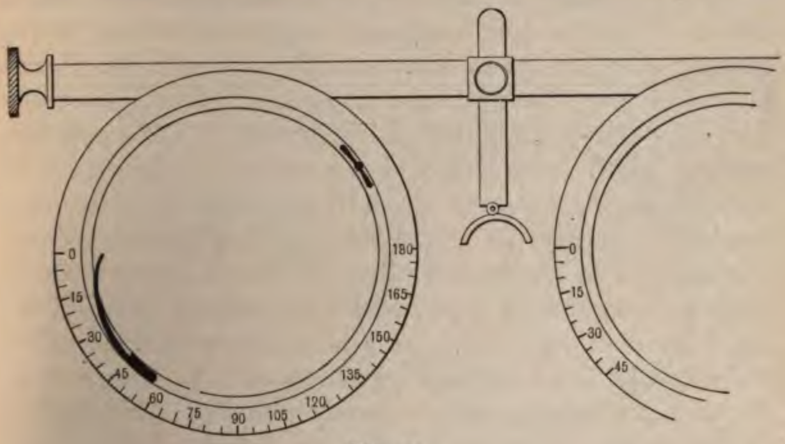

FIG. 97.

FIG. 98.

the record would be so many degrees of inclination to the nasal side; or, if the upper end of the cylinder was inclined toward

the temple, the record would be so many degrees to the temporal side.

For example, in the right eye 15° nasal would mean axis 75

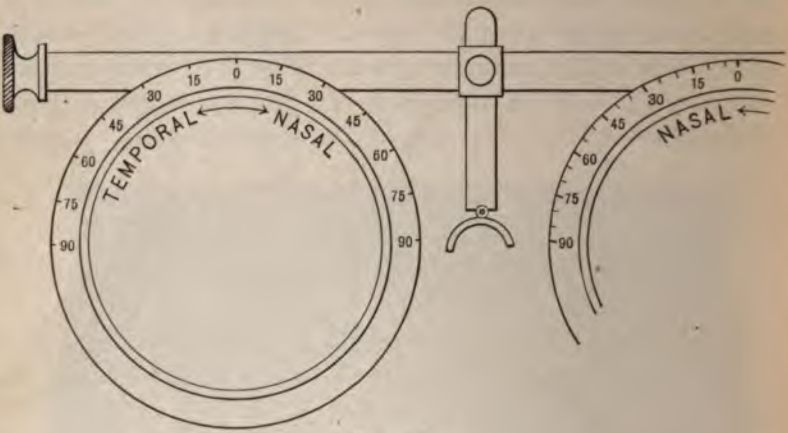

Fig. 99.

on the ordinary trial-frame, and 15° temporal would mean 105°.

By turning the milled wheel at the side of the frame toward the temple, the cylinder lens can be made to revolve to any desired axis.

Fig. 100.

The trial-case also contains other accessories, such as blanks or blinders, a stenopeic slit, pin-hole disc (Fig. 100), etc., all of which are referred to in the text.

Combination of Lenses.—The sign of combination is ○.

Combining Spheres.—Any number of spheric lenses placed with their optic centers over each other, and surfaces together, *will equal one* lens the value of their sum: for example, +2 S.

$\bigcirc$ +1 S. $\bigcirc$ +3 S. will equal +6 S.; or a −2 S. $\bigcirc$ −1 S. $\bigcirc$ −3 S. will equal a −6 S.

If a plus and minus sphere, each of the same strength, be placed with their surfaces together (optic centers over each other), the refraction will be nothing, for one will neutralize the effect of the other; for instance, +4 S. and −4 S. will be equivalent to a piece of plane glass, as the −4 S. will diverge rays of light as much as the +4 S. will converge them, and the result is, rays of light parallel before refraction are parallel after passing through such a combination. If, however, a plus and a minus sphere of different strengths are placed together, the value of the resulting lens will equal their difference, in favor of the higher number; for instance, +4 S. and −2 S. will equal a +2 S., the −2 S. neutralizing 2 S. of the +4 S., leaving +2 S.

Combining Cylindric Lenses.—Any number of cylindric lenses placed together, with their axes in the *same* meridian, are equal to a cylinder the value of their sum; for example, +2 cyl. axis 90° and +3 cyl. axis 90° will equal a +5 cyl. axis 90°; or −2 cyl. axis 180° and −3 cyl. axis 180° will equal a −5 cyl. axis 180°; or −2 cyl. axis 180° and +1 cyl. axis 180° will equal a −1 cyl. axis 180°.

As a cylinder refracts rays of light only in the meridian opposite to its axis, this opposite meridian can always be found by the following simple rule:

"*Add* 90 *when the given axis is* 90 *or less than* 90, *and subtract* 90 *when the given axis is more than* 90."

For example: +3 cyl. axis 90 refracts rays of light in the 180° meridian (90 + 90 = 180); or +3 cyl. axis 75 refracts rays of light in the 165° meridian (75 + 90 = 165). A −3 cyl. axis 135 refracts rays of light in the 45° meridian (135 less 90 = 45). A −2 cyl. axis 180 refracts rays of light in the 90° meridian (180 less 90 = 90).

Combining two cylinders of the same strength and same denomination, with their axes at right angles to each other, will equal a sphere of the same strength and same denomina-

tion. For instance, +3 cyl. axis 90 and +3 cyl. axis 180, placed together, will equal a +3 S.; *i.e.*, the +3 cyl. at axis 90 will converge parallel rays in the 180 meridian, while the +3 cyl. axis 180 will converge parallel rays in the 90 meridian, producing a principal focus; therefore any sphere is also equal to two cylinders of its same strength and same denomination with their axes at right angles to each other.

Combining cylinders of different strength, but of the same denomination, with their axes at right angles to each other, such a combination will equal a sphere and a cylinder of the same denomination. For example: +2 cyl. axis 75 ○ +3 cyl. axis 165 will equal +2 S. ○ +1 cyl. axis 165. The +2 cyl. axis 75 takes +2 of the +3 cyl. axis 165 and makes a +2 S., leaving +1 cyl. axis at 165; the result is then +2 S. ○ +1 cyl. axis 165.

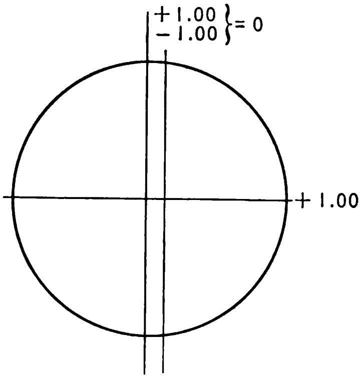

FIG. 101.

Or −3.50 cyl. axis 15 ○ −4.50 cyl. axis 105, will equal −3.50 S. ○ −1 cyl. axis 105. The −3.50 axis 15 takes −3.50 of the −4.50 and makes a −3.50 S., leaving −1 cyl. axis 105; this −1 cyl. axis 105 is now joined to the −3.50 sphere, making −3.50 S. ○ −1 cyl. axis 105.

Combining a sphere and a cylinder of the same strength, but of different denomination, will equal a cylinder of the opposite sign and opposite axis from the cylinder given. For example: +1 sphere ○ −1 cyl. axis 180 will equal +1 cyl. axis 90. The +1 S. equals two +1 cyls. one at axis 90 and one at axis 180, and the −1 cyl. at axis 180 is neutralized by the +1 cyl. at the same axis, leaving the +1 cyl. axis 90. This may be better understood by the diagram (Fig. 101).

Or −3 S. ○ +3 cyl. axis 90 equals −3 cyl. axis 180. The

−3 S. is equal to two −3 cyl., one at axis 90 and one at axis 180; the one at axis 90 is neutralized by the +3 cyl. at the same axis, leaving −3 cyl. axis 180.

Combining a Sphere with a Weaker Cylinder of Different Denomination.—Such a combination should be changed to its simplest form of expression, and will equal a sphere of the same denomination, of the value of their difference, combined with a cylinder of the same strength as the cylinder given, but of opposite sign and axis. For example: +4 S. ○ −1 cyl. axis 180. The −1 cyl. is refracting in the 90° meridian; therefore it reduces the strength of the +4 S. in this axis, making it a +3. The horizontal or 180° meridian of the +4 S. has not been altered, but still remains +4, and the result is +3 in the vertical meridian and +4 in the horizontal meridian, equaling, therefore, +3 S. ○ +1 cyl. axis 90.

The following rule will be of service in making this change, and, in fact, this rule will apply in any instance in which the sphere and cylinder are of different denomination, no matter what their respective strengths may be:

Rule.—*Subtract the less from the greater, and to the result prefix the sign of the greater; combine with this the same strength cylinder, using the opposite sign and opposite axis.* Example: +2.25 S. ○ −0.75 cyl. axis 75°; subtracting the less from the greater (−0.75 from +2.25), and prefixing the sign of the greater (+), will leave +1.50 S.; and combining with this the same strength cylinder (0.75), with opposite sign and axis (+ and 165), will be +0.75 cyl. axis 165. Result, +1.50 S. ○ +0.75 cyl. axis 165.

Combining a Sphere and Cylinder of the Same Denomination—This is recognized as the minimum or simplest form of expression, and is *seldom* changed. For example: −2 S. ○ −6 cyl. axis 180 is considered as the thinnest lens and the one with the least weight that can be made by such a combination. It may be changed, however, by the reverse of the rule above given, and will equal −8 S. ○ +6 cyl. axis 90.

Combining Two Cylinders of Diffierent Denominations with Opposite Axes.—Commonly called crossed cylinders. Such combinations can be written in three ways:

1. +Cyl. $\bigcirc$ −cyl. axes opposite.
2. +Sphere $\bigcirc$ −cyl. (cylinder stronger than sphere).
3. −Sphere +cyl. (cylinder stronger than sphere).

For example: −1.00 cyl. axis 180 $\bigcirc$ +2.50 cyl. axis 90 may be changed to one of the following:

−1.00 S. $\bigcirc$ +3.50 cyl. axis 90; or
+2.50 S. $\bigcirc$ −3.50 cyl. axis 180.

The first formula shows that the vertical meridian must always be −1 and the horizontal or 180 meridian must always be +2.50, and with this clearly in mind, the second and third formulas will be understood. In the second formula (−1.00 S. $\bigcirc$ +3.50 cyl. axis 90) the +3.50 cyl. is only equal to +2.50, as it has 1 D. neutralized by −1 of the −1 sphere. In the third formula (+2.50 S. $\bigcirc$ −3.50 cyl. axis 180) the −3.50 cyl. is only equal to −1.00 cyl., as it has −2.50 neutralized by +2.50 of the sphere.

In any spherocylindric combination the meridian in which the axis of the cylinder lies has the strength of one lens, and the meridian opposite to the axis of the cylinder has the combined values of sphere and cylinder; i.e., −1.00 S. $\bigcirc$ +3.50 cyl. axis 90 means −1.00 on the axis (90) of the cylinder, and opposite to the axis therefore at 180, it equals +2.50 (−1 and +3.50).

Crossed cylinders in themselves are seldom ordered in a prescription, preference being given to a spherocylindric combination. When to order a plus sphere with a minus cylinder, and when to order a minus sphere with a plus cylinder, depends upon the individual lenses. For example: +0.50 cyl. axis 90 $\bigcirc$ −5.00 cyl. axis 180 equals +0.50 S. $\bigcirc$ −5.50 cyl. axis 180 or −5 S. $\bigcirc$ +5.50 cyl. axis 90.

Preference would be given to the plus sphere combination, on account of thinness and lesser weight of the lens. The follow-

ing formula, -1 cyl. axis 180° $\bigcirc$ $+3$ cyl. axis 90° equals -1.00 S. $\bigcirc$ $+4$ cyl. axis 90, or $+3$ S. $\bigcirc$ -4 cyl. axis 180, and for similar reasons preference would be given to the *minus* sphere combination. Whichever combination makes the thinnest and lightest weight of glass is the one to be ordered, as a rule.

The student should practise these combinations at the trial-case, and be able at a glance to change one formula into another without diagram or rule.

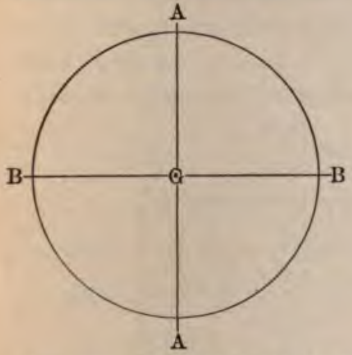

FIG. 102.—The dot in G at the point of crossing of BB with AA indicates the optic and geometric centers superimposed.

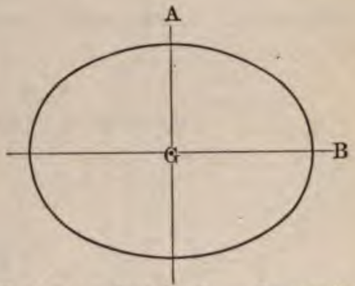

FIG. 103.—Dot in G = Geometric center.

Combining a Prism with a Sphere, Cylinder or Spherocylinder.—Before taking up the consideration of prism combinations, the reader must be acquainted with the following:

The geometric center of a lens is a point midway of the diameters of the surface; therefore there is a geometric center for each surface and these are superimposed. As the geometric center is always controlled by the midpoint of the diameters, it is easily located. Figure 102 shows a circle which may be considered as the outline or contour of a lens. AA and BB are diameters. The dot in the G is the midpoint of these diameters and is therefore the geometric center. As another illustration, see Fig. 103. This is the outline of a spectacle

lens; AA and BB represent the two chief diameters and the dot in the G is the midpoint of these diameters and hence is the geometric center. Also see dot on surfaces of lens pictured in Fig. 104.

Optic Center.—This term is used synonymously with nodal point, but it is not and must not be confused with the geometric center. The optic center is the point where secondary rays cross the axial ray (dot in the O, Fig. 104). Rays of light crossing the optic center in thin lenses are not considered as undergoing refraction (SA in Fig. 104). The optic center is always a

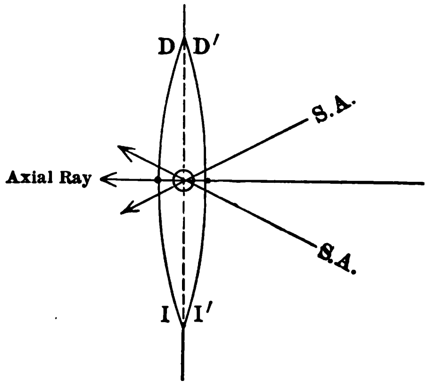

FIG. 104.—Dot in O = Optic center. Dots = Geometric centers.

fixed point and may be located at any part of the lens or at an imaginary point beyond its edge. In Fig. 104 the optic and geometric centers coincide, but in Fig. 105 they do not coincide. To summarize, the optic center is always at the thickest part of a convex lens and the thinnest part of a concave lens.

True Center of a Lens.—A lens is said to be centered when the optic and geometric centers coincide or are both on the visual axis (Figs. 104 and 106).

When the optic and geometric centers do not coincide, then such a lens has a prism effect or combination; hence (Fig. 105).

1. The nearer the optic and geometric centers coincide with *or approximate* the axial ray the less the prismatic effect.

2. The farther apart the optic and geometric centers the greater the prismatic effect (Fig. 105).

3. In weak lenses or lenses with long radii of curvature, a slight lateral displacement of the optic center produces but little prismatic effect.

4. In strong lenses or those with short radii of curvature, a slight lateral displacement of the optic center from the geometric center will produce considerable prismatic effect.

Or 3 and 4 may be restated briefly; *i.e.*, a strong lens requires less lateral displacement of the optic center from the geometric center than a weak lens to obtain the same amount of prismatic effect in each.

Unless otherwise prescribed, every lens placed before the

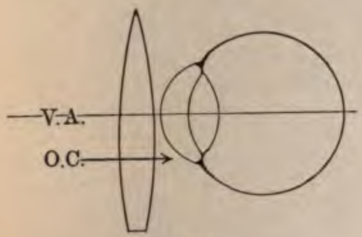

FIG. 105.

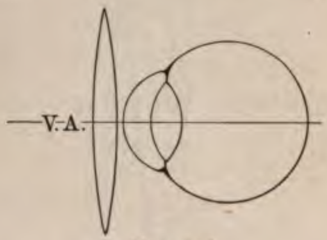

FIG. 106.

patient's eye is supposed to have the optic and geometric centers coincide with the visual axis of the eye (Fig. 106); then there will not be any prismatic effect. If there is any departure from this correct position for the lens and the eye together, then a prismatic effect is produced and its amount is in proportion to the displacement or separation and the strength and variety of the lens in use (Fig. 105). (See Punctal lens.)

Decentering (Decentring) a Lens.—This may be described as having the optic center of a lens laterally displaced from the geometric center, so that the eye looking through such a lens sees through the geometric center but not the optic center (Fig. 105). In other words the geometric center is on the visual axis but the optic center is to one side (Fig. 105).

A decentered lens may therefore be described as one whose optic and geometric centers do not coincide (Figs. 105, 109, 110, 111 and 113).

When ordering a prism in combination with a lens the prescriber may write his prescription out in full or he may specify that the lens is to be decentered. For instance +4 sphere $\bigcirc$ 4^{Δ} base down. This is equivalent to a plano +2 sphere[1] on each surface of the 4 prism (Fig. 107).

The optician would, however, take a +4 sphere (in the

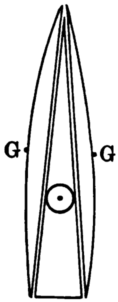

FIG. 107.—Dots at GG = Geometric centers. Dot in O = Optic center of this combination.

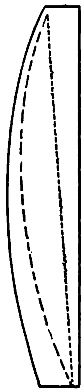

FIG. 108.—Plano-convex sphere in the rough. Straight dotted line for a plano-sphero-prism. Curved dotted line for meniscus sphero-prism.

rough[2] as he calls it) and grind or polish the other surface at an angle as indicated by the straight dotted line (see Fig. 108). The angle at which he grinds the second surface must be in keeping with the prismatic effect which the prescription calls for.

In place of the above formula the prescriber could have ordered +4 sphere decentered 10 mm. downward. For this prescription the optician would take the +4 sphere and mark

[1] It might be well to mention that the optician carries spheric lenses in stock that are round or circular in contour and cylinders that are square.

[2] *In "the rough"* means that one surface or edge is not polished or finished.

with a dot the true center (dot 1 in Fig. 109) and also mark the shape of the lens he is to cut out and in place of cutting it as indicated by the dotted line, follows the continuous line and in this way leaves the optic center 10 mm. downward or below the geometric center at 2. In profile (Fig. 110) this +4 spheric lens shows the prism thus manufactured by decentering.

The prismatic effect of decentering a plus sphere is always produced in the direction of the decentering, whereas when de-

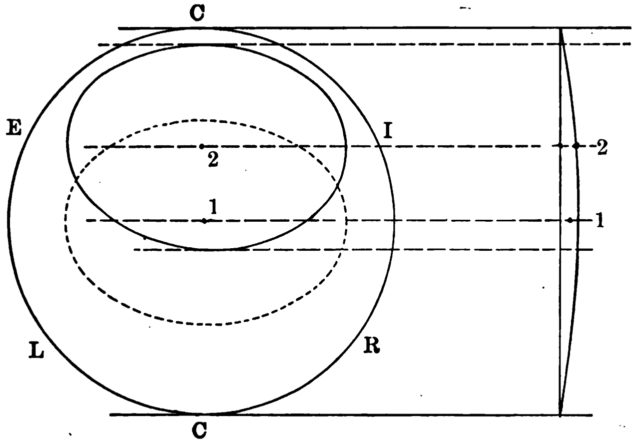

FIG. 109. FIG. 110.

FIG. 109.—CIRCLE = plano-convex lens in the rough. I = optic and geometric centers superimposed. At 2 the geometric center is above.

FIG. 110.—Profile of Fig. 109 showing geometric center at 2 and optic center at 1.

centering a minus sphere the prismatic effect is always produced in the direction opposite to the direction of the decentering; for instance, decentering a +4 sphere 10 mm. upward produces 4 prism-diopters upward, whereas decentering a −4 sphere 10 mm. upward produces 4 prism-diopters downward.

The rule for decentering lenses to obtain a certain amount of prismatic effect is as follows:

"For every centimeter (10 mm.) of decentering there will be produced as many centrads or prism-diopters as there are

diopters **in the meridian** which is decentered." In the example just given (+4 sphere ⬭ 4^{Δ} base downward) it must first of all be remembered that this is a 4 diopter lens and secondly if the optic center is placed 10 mm. away from the geometric center the effect will be a +4 sphere ⬭ 4 prisms; in other words, as previously mentioned, it will be +4 sphere decentered 10 mm. downward (Figs. 109 and 110). According to the same rule if the +4 sphere had been decentered 5 mm. the effect would have been 2 prisms, if it had been decentered 2½ mm. the effect would have been 1 prism, if it had been decentered 15 mm. the effect would have been 6 prisms. Likewise if the denominator of the sphere had been a minus in place of a plus, the effect would have been the same, also if a plus or minus 1, 2, 3, 5, 6, 7, 8, etc., was decentered 10 mm., the prismatic effect would be 1, 2, 3, 5, 6, 7, 8, etc., centrads or prism-diopters respectively. If the sphere is plus or minus 0.25, 0.50 or 0.75 and is decentered 10 mm. the prismatic effect is ¼, ½, and ¾ of a centrad or prism-diopter respectively. Another rule for decentering is to multiply the number of prisms in the prescription by 10 and divide the amount by the number of diopters **in the meridian** which is to be decentered and the quotient will be the number of millimeters for decentering. In the above example, +4 sphere ⬭ 4^{Δ} base down, the number of prisms is 4 and multiplying 4 by 10 equals 40, dividing this amount by 4 (the number of the diopters in the meridian of 90°) and the quotient is 10 mm., namely +4 sphere decentered 10 mm. downward.

Combining a prism with a cylinder (plus or minus) requires extra consideration, as it depends in which meridian the base-apex line of the prism is to be placed and which meridian is to be decentered. The reader must remember that a cylinder does not refract rays of light in the meridian corresponding to its axis. Figure 111 shows a +4 cylinder axis 90°. Opposite to axis 90° (that is in the 180 meridian), the strength of the *cylinder is* +4, but on axis 90° there is no curve to the glass,

and there is therefore no refraction in the 90° meridian. Outlining the spectacle lens on the surface of the cylinder as indicated by the figure 1 in Fig. 111, there would not be any prismatic effect produced if this lens was thus cut out of the cylinder, but if the lens outlined below was cut out, then the prismatic effect would be 4 centrads or prism-diopters because the geometric center would then be 10 mm. to one side of the axis. Namely, +4 cyl. axis 90 ○ 4^{Δ} base in axis 180° is equal to a +4 cyl. axis 90° decentered 10 mm. in, on axis 180°.

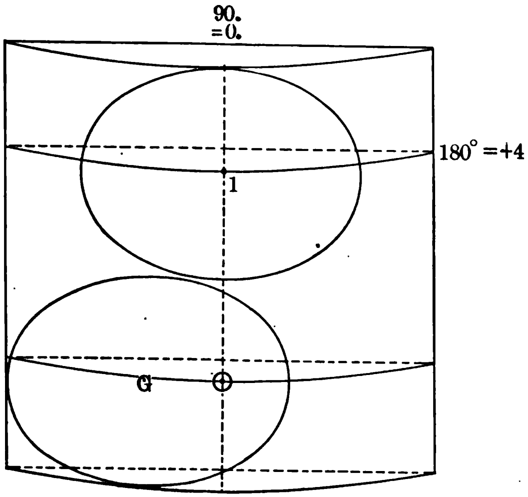

FIG. 111.

From the above statements, the following may be deducted:

1. A cylinder *per se* cannot be decentered on its axis.

2. Decentering a cylinder 1 cm. in the meridian at right angles to its axis will produce the effect of as many prism-diopters or centrads as there are diopters in the cylinder. Plus or minus 1, 2, 3, 4, 5, or 6 cylinder axis 90°, decentered 10 mm. on the meridian of 180° will give the effect of 1, 2, 3, 4, 5, and 6 prism-diopters or centrads respectively. The same rule applies to 0.25, 0.50 and 0.75 cylinder axis 90°. The equivalent

of +4 cyl. axis 180 $\bigcirc$ 4^{Δ} base down is a 4^{Δ} base down with a +4 cyl. axis 180 superimposed or as in Fig. 112 the optician will take a +4 cyl. axis 180° in the rough and grind the other surface plane (see dotted line same figure) and at an angle which would produce the desired prismatic effect—in this instance 4.

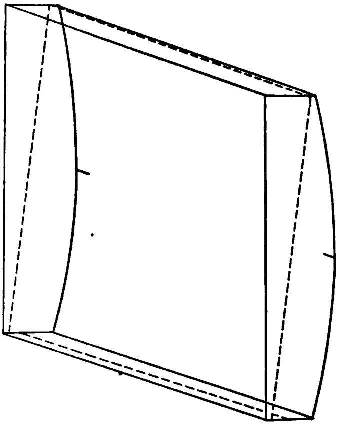

FIG. 112.—Cylinder in the rough marked with dotted lines ready to be ground to get the prism combination.

Combining a Prism with a Plus or Minus Cylinder which has its Axis Obliquely Placed to the Base-apex Line of the Prism

For instance, +4 cyl. axis 45 $\bigcirc$ 2^{Δ} base in, base-apex line on 180 meridian. This is equivalent to a 2^{Δ} base in and a +4 cyl. axis 45 superimposed, or the optician takes the +4 cyl. in the rough and grinds the opposite surface plane and at an angle to give the desired prismatic effect. In this formula for the purpose of decentering it is necessary to know the dioptric strength of the +4 cyl. in the 180 meridian when the axis of the cylinder is at 45°. Figure 113 shows such a cylinder with its axis at 45°. The meridians of 90°, 180° and 135° are also shown. If the *spectacle lens* indicated by the continuous line were cut out of

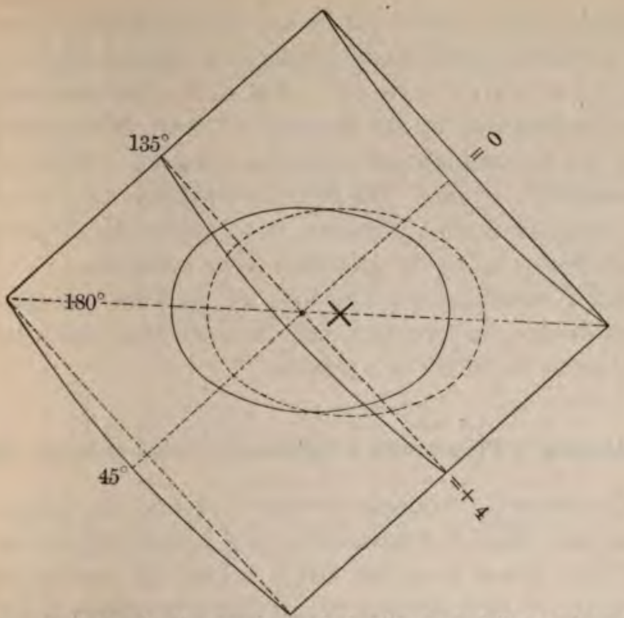

FIG 113.—Cylinder in the rough marked with dotted line and an × ready to be cut, thus producing a decentered cylinder

FIG. 114.—Geneva lens measure.

the cylinder, there would not be any prismatic effect produced as the geometric center and cylinder axis coincide and it would simply be a +4 cyl. axis 45°. But if the spectacle lens was cut out as indicated by the dotted line, then there would be a 2^{Δ} base in, in combination with the cylinder. This cylinder was decentered 10 mm. The method of finding out the strength of any cylinder in any meridian is to apply the Geneva lens measure (Fig. 114) to the meridian to be decentered.

In other words, a +4 cyl. axis 45° has the strength of 2 diopters in the 180 meridian and decentering a 2 diopter lens 10 mm. gives the effect of 2 prisms.

Combining a Prism with a Sphero-cylinder of Same Sign

In the following example +1.00 ⊂⊃ +3.00 cyl. axis 90 ⊂⊃ 1^{Δ} base out. This is equivalent to a +1.00 sphere on one surface of the 1 prism base out and a +3.00 cyl. axis 90° on the other surface. Or if decentered, all that is necessary to remember is that in the 180 meridian, where the decentering is to be done, there are 4 diopters, 1 for the sphere and 3 for the cylinder, and to get the effect of a 1 prism in 4 diopters the sphero-cylinder must be decentered 2½ mm., namely, +1.00 sphere ⊂⊃ +3.00 cyl. axis 90° decentered 2½ mm. outward.

If this sphero-cylinder had been decentered in the same meridian 5, 7½ or 10 mm., the prismatic effect would have been 2, 3 and 4 prisms respectively. This applies of course to the 180 meridian, but if the decentering had been done in the vertical meridian, then the calculations would be entirely different, for it will be observed that in the meridian of 90° there is only 1 diopter. If the sphero-cylinder to be decentered contains a plus sphere with a minus cylinder, the prescriber must remember that one neutralizes the other to a certain extent and he must calculate accordingly; for example, in −1, sphere ⊂⊃ +3.00 cyl. axis 90° ⊂⊃ 2^{∇} base out, axis 180°, this sphero-*cylinder* would have to be decentered 10 mm. as follows: −1

JACKSON: DECENTERING OF LENSES FOR PRISMATIC EFFECTS, WITH GLASS HAVING AN INDEX OF REFRACTION OF ABOUT 1.54[1]

Power of lens in diopters	To obtain 1° prism	To obtain 2° prism	To obtain 3° prism	To obtain 4° prism	To obtain 5° prism	To obtain 6° prism	To obtain 8° prism	To obtain 10° prism
	Decenter mm.	Decenter mm.	Decenter mm.	Decenter mm.	Decenter mm.	Decenter mm.	Decenter mm.	Decenter mm.
1 D.	9.4	18.8	28.3	37.7	47.2	56.5	75.8	95.2
2	4.7	9.4	14.1	18.8	23.6	28.2	37.9	47.6
3	3.1	6.3	9.4	12.6	15.7	18.8	25.3	31.7
4	2.3	4.7	7.1	9.4	11.8	14.1	18.9	23.8
5	1.9	3.8	5.7	7.5	9.4	11.3	15.2	19.0
6	1.6	3.1	4.7	6.3	7.9	9.4	12.6	15.9
7	1.3	2.7	4.0	5.4	6.7	8.1	10.8	13.5
8	1.2	2.3	3.5	4.7	5.9	7.1	9.5	11.9
9	1.0	2.1	3.1	4.2	5.2	6.3	8.4	10.5
10	0.9	1.9	2.8	3.8	4.7	5.6	7.6	9.5
11	0.9	1.7	2.6	3.5	4.3	5.1	6.9	8.7
12	0.8	1.6	2.4	3.1	3.9	4.7	6.3	7.9
13	0.7	1.4	2.2	2.9	3.6	4.3	5.8	7.3
14	0.7	1.3	2.0	2.7	3.4	4.0	5.4	6.8
15	0.6	1.3	1.9	2.5	3.1	3.8	5.1	6.3
16	0.6	1.2	1.8	2.4	3.0	3.5	4.7	6.0
17	0.6	1.1	1.7	2.2	2.1	3.4	4.5	5.6
18	0.5	1.0	1.6	2.1	2.6	3.1	4.2	5.3
19	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0
20	0.5	0.9	1.4	1.9	2.4	2.8	3.8	4.8

[1] *Transactions* of the American Ophthalmological Society.

EQUIVALENT NUMBERS OF PRISMS—JACKSON[1]

The first column gives the number of each prism according to the new system, indicating its power of causing deviation in the rays of light passing through it expressed in *centrads*. The second column gives the same deviating power expressed in *prism diopters*. The third column gives the refracting angle of the prism (its number by the old system) which will cause this same deviation, when the prism has one surface perpendicular to the rays and the glass has an index of refraction of 1.54.

Deviation in centrads	Deviation in prism diopters	Refracting angle in degrees	Deviation in centrads	Deviation in prism diopters	Refracting angle in degrees	Deviation in centrads	Deviation in prism diopters	Refracting angle in degrees
1	1.00	1.06	9	9.02	9.39	17	17.16	16.98
2	2.00	2.12	10	10.03	10.39	18	18.19	17.85
3	3.00	3.18	11	11.03	11.37	19	19.23	18.68
4	4.00	4.23	12	12.04	12.34	20	20.26	19.45
5	5.00	5.28	13	13.06	13.29	25	25.53	23.42
6	6.01	6.32	14	14.08	14.23	30	30.93	26.81
7	7.01	7.35	15	15.11	15.16	40	42.38	32.18
8	8.02	8.38	16	16.14	16.08	50	54.62	36.03

[1] Dr. Edward Jackson, *Ophthalmic Review*.

DR. JAMES WALLACE'S[1] TABLE GIVING THE DEGREE OF THE PRISM AND THE ANGLE OF ROTATION TO PRODUCE THE EFFECT OF TWO PRISMS WITH THEIR BASES AT RIGHT ANGLES

Prisms required	Deg. of prism	Ang. of rotation	Prisms required	Deg. of prism	Ang. of rotation	Prisms required	Deg. of prism	Ang. of rotation	Prisms required	Deg. of prism	Ang. of rotation	Prisms required	Deg. of prism	Ang. of rotation
	°	° ′		°	° ′		°	° ′		°	° ′		°	° ′
1 × 1	1.4	45.0	1 × 2	2.2	26.34	1 × 3	3.2	18.26	1 × 4	4.1	14.02	1 × 5	5.1	11.19
2 × 1	2.2	63.26	2 × 2	2.8	45.0	2 × 3	3.6	33.42	2 × 4	4.5	26.34	2 × 5	5.4	21.48
3 × 1	3.2	71.34	3 × 2	3.6	56.18	3 × 3	4.2	45.0	3 × 4	5.0	36.02	3 × 5	5.8	30.58
4 × 1	4.1	75.58	4 × 2	4.5	63.26	4 × 3	5.0	53.08	4 × 4	5.7	45.0	4 × 5	6.4	38.40
5 × 1	5.1	78.41	5 × 2	5.4	68.12	5 × 3	5.8	59.02	5 × 4	6.4	51.20	5 × 5	7.0	45.0
6 × 1	6.1	80.32	6 × 2	6.3	71.33	6 × 3	6.7	63.26	6 × 4	7.2	56.18	6 × 5	7.8	50.11
7 × 1	7.1	81.52	7 × 2	7.3	74.03	7 × 3	7.6	66.47	7 × 4	8.0	60.14	7 × 5	8.6	54.27
8 × 1	8.0	82.51	8 × 2	8.2	75.57	8 × 3	8.5	69.26	8 × 4	8.9	63.25	8 × 5	9.4	57.59
9 × 1	9.0	83.39	9 × 2	9.2	77.27	9 × 3	9.5	71.33	9 × 4	9.8	66.01	9 × 5	10.3	60.56
10 × 1	10.0	84.17	10 × 2	10.2	78.18	10 × 3	10.4	73.09	10 × 4	10.8	68.10	10 × 5	11.2	63.25
1 × 6	6.1	9.28	1 × 7	7.1	8.8	1 × 8	8.0	7.09	1 × 9	9.0	6.21	1 × 10	10.0	5.43
2 × 6	6.3	18.27	2 × 7	7.3	15.57	2 × 8	8.2	14.03	2 × 9	9.2	12.33	2 × 10	10.2	11.42
3 × 6	6.7	26.34	3 × 7	7.6	23.13	3 × 8	8.5	20.34	3 × 9	9.5	18.27	3 × 10	10.4	16.51
4 × 6	7.2	33.42	4 × 7	8.0	29.46	4 × 8	8.9	26.35	4 × 9	9.8	23.59	4 × 10	10.8	21.50
5 × 6	7.8	39.49	5 × 7	8.6	35.33	5 × 8	9.4	32.01	5 × 9	10.3	29.04	5 × 10	11.2	26.35
6 × 6	8.4	45.0	6 × 7	9.2	40.37	6 × 8	10.0	36.53	6 × 9	10.8	33.42	6 × 10	11.7	30.59
7 × 6	9.2	49.23	7 × 7	9.9	45.0	7 × 8	10.6	41.11	7 × 9	11.4	37.44	7 × 10	12.3	35.01
8 × 6	10.0	53.07	8 × 7	10.6	48.49	8 × 8	11.3	45.0	8 × 9	12.1	41.39	8 × 10	12.8	38.40
9 × 6	10.8	56.18	9 × 7	11.4	52.06	9 × 8	12.1	40.21	9 × 9	12.8	45.0	9 × 10	13.5	42.0
10 × 6	11.7	59.01	10 × 7	12.3	54.59	10 × 8	12.8	51.20	10 × 9	13.5	48.0	10 × 10	14.1	45.0

If the base of a prism is rotated 36° 53′ from the vertical meridian, it is 53° 7′ from the horizontal meridian. The prismatic effect in the vertical meridian, 36° 53′ from the base of the prism, is 3/10 of the prism. The prismatic effect in the horizontal meridian, 53° 7′ from the base of the prism, is 9/10 the value of the prism. The base of the prism is rotated a smaller arc for the larger effect and *vice versa*. The direction of the base is the direction of the perpendicular to the base.

[1] Oculist's Vade Mecum.

sphere ◯ +3 cyl. axis 90° decentered 10 mm. outward. Finally, a decentered lens differs in no respect optically from a lens which contains a prism.

A very important fact to remember in the ordering of lenses to be decentered is that many lenses are not of sufficient width or strength to permit of decentering, especially if the lens is weak and the prism is strong. For instance, the following: +0.50 sph. ◯ 4^{∇} base up. This should be made by taking a +0.50 sphere in the rough and cutting off the second surface at the angle which would produce the 4^{∇} base up (Fig. 108). If the prescriber wrote this formula for decentering as follows: +0.50 sph. decentered 80 mm. (8 cm.) upward, he would find that such a prescription would display great ignorance and invite suspicious criticism of the prescriber's knowledge. Weak lenses do not come large enough for any such purpose.

The foregoing tables by Dr. Jackson and Dr. Wallace are self-explanatory:

Prescription Writing.—In writing prescriptions for lenses the right eye is indicated by one of three signs: R, Rt, or O. D., the last from the Latin for right eye, *Oculus Dexter*. The left eye is also indicated in one of three ways: L, Lt, or O. S., the last from the Latin for left eye, *Oculus Sinister*.

A prescription may call for any one of the following:

+Sphere, written +4 D. or +4.00 D. S. or +4 S. or +4 sph. or +4 D. periscopic or +4 D. meniscus.
−Sphere, written −2 D. or −2.00 D. S. or −2 S. or −2 sph. or −2 D. periscopic or −2 D. meniscus.
+Cylinder, written +4.00 D. C. or +4 C. or +4 cyl. (axis as indicated).
−Cylinder, written −2.00 D. C. or −2 C. or −2 cyl. (axis as indicated).
+Sphere and +cylinder, written +2.00 S. ◯ +2.00 cyl. axis 90°.
−Sphere and −cylinder, written −2.00 S. ◯ −2.00 cyl. axis 180°.
+Sphere and −cylinder (cylinder stronger than sphere), +2.00 S. ◯ −3.00 cyl. axis 180°.
−Sphere and +cylinder (cylinder stronger than sphere), −2.00 S. ◯ +3.00 cyl. axis 90°.

A plus with and minus cylinder *may* be prescribed and, if *so, their axes* must be at right angles to each other. An oc-

casional exception to this may be found in irregular astigmatism. Or a prism with its base indicated may be added in any one of the foregoing formulas; for example: −2 S. ⊂ −2.00 cyl. axis 180 ⊂ 2 Δ base in; or the direction of the base may be abbreviated as follows: B. I., meaning base in; B. O., meaning base out; B. U., meaning base up; and B. D., meaning base down.

Prescriptions are never written for two spheres.

Prescriptions are never written for two cylinders at the same axis.

Prescriptions are never written for two cylinders at axes other than those at right angles to each other, except, as just noted, in irregular astigmatism.

For obvious reasons prescriptions are never written for a sphere and two cylinders.

Toric Lens (*torcine* or *torique*, "twisted").—This lens is one which has, combined on one surface, the optic effect of a sphero-cylinder lens, or two cylinders of different strength at right angles to each other; this is illustrated in Fig. 115, showing both the convex and the concave toric; these are, however, of the plano variety, whereas the usual toric lenses are of the meniscus variety; that is to say, they usually have a concave surface toward the eye (see Fig. 115 A). The sphero-cylinder lens in position is shown in Fig. 115 B, and is not toric. The toric lens is very acceptable in many instances, as it is thinner than an ordinary lens and can be fitted closer to the eyes and so give a larger field of vision. Toric lenses, to a limited extent, protect the eyes from foreign bodies by reason of their shape and greater proximity to the eyes. In many cases they appear lighter than sphero-cylinder equivalents. The surface of the toric lens being more concentric with the globe of the eye,

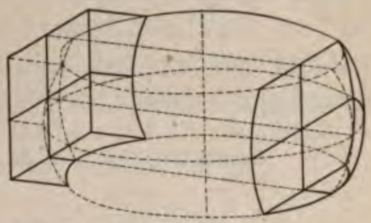

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FIG. 115.

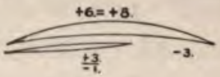
movements of the eye on the visual axis will be less oblique to the inner surface of the glass, and the distance of the eye

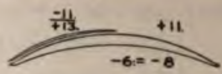
Fig. 115 A.

Fig. 115 B.

from the different points of the glass will be more equal. These advantages render toric lenses particularly valuable to all

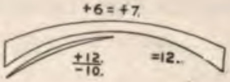
BASE CURVE — 6. D. **BASE CURVE + 6. D**

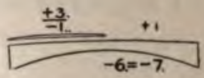




+ 3. D sph ⌶ + 2. D cyl

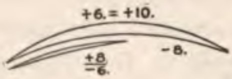
Fig. 116. Fig. 117.

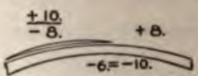




— 5. D. sph ⌶ — 1 D. cyl

Fig. 118. Fig. 119.





+ 2. D. sph. ⌶ — 4 D. cyl.

Fig. 120. Fig. 121.

whose occupations or pleasures require frequent movements of *the eyes.* However, if the lenses are already strongly concave,

the writer would advise against toric lenses as the additional concavity will in many instances produce fatigue from the resulting photophobia. And, too, if the lenses are strongly convex, similar discomfort may result. The writer seldom prescribes toric lenses if the formula contains a number higher than 3 diopters, sphere or cylinder. Figures 116, 117, 118, 119, 120, and 121 are samples of toric lenses with bifocal segments and their formulas.

Punctal Lenses.—While the periscopic, meniscus and toric forms of lenses are superior to the so-called flat lenses, yet there has been a demand for a lens that would eliminate entirely the astigmatic errors, which result from the oblique pencils falling on the flat form of lenses. The Punctal Lens made by Carl Zeiss of Jena and reproduced in America by the Bausch and Lomb Company, is the consummation of the ideal ophthalmic lens as it does away with most of the blur and distortion that is observed when looking through a lens near its margin.

Recognition of Lenses.

A convex sphere is thick at the center and thin at the edge. It has the power of converging rays of light; hence, if strong, it is a burning glass. Objects viewed through a convex lens as it is moved before the eye, from left to right and right to left or up and down, appear to move in an opposite direction to that in which the lens is moved. The weaker the lens, the slower the object appears to move; and the stronger the lens, the faster the apparent movement of the object. A convex lens, being a magnifier, has the effect of making objects appear larger and closer when it is moved away from the observer's eye; or if brought toward the eye, objects already enlarged appear smaller and more distant.

To Find the Optic Center of a Convex Lens.—Looking at a vertical straight line and passing a convex lens before the eye from left to right has the effect of displacing toward the right edge of the lens that portion of the line seen through the lens (see Fig. 122), and as the lens is slowly moved still farther to

the right, the displaced portion of the line will finally coincide with the original straight line, making one continuous line through the lens (see Fig. 123). This straight line may be marked on the surface of the lens with pen and ink or a pointed match stick dipped in white lead paint, and then turning the lens to the opposite meridian and repeating the examination, and marking the lens as before, the optic center will be in the lens beneath the point of intersection of the two lines (see Fig. 124).

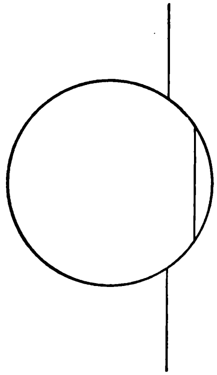


FIG. 122.

A concave sphere is thick at the edge and thin at the center, and has the power of causing rays of light to diverge. When moved before the eye from left to right and right to left or up and down, objects appear to move in the same direction as that in which the lens is moved.

A concave lens being a minifier, makes objects appear smaller

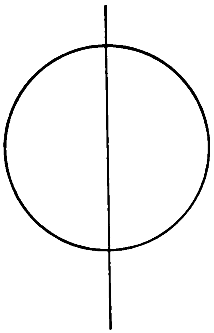


FIG. 123.

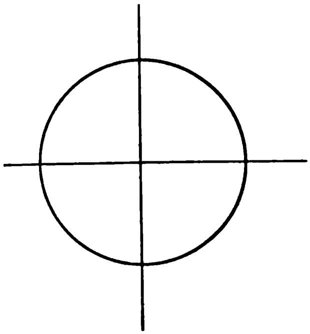


FIG. 124.

and more distant as the glass is moved away from the eye, and if brought closer to the eye, makes objects already small appear somewhat larger and nearer. Looking at a straight edge or *line through a* concave sphere, and passing the lens from left to

right, the portion of the line seen through the lens appears displaced toward the center of the lens (see Fig. 125), and as the lens is still farther moved to the right, the displaced portion of the line finally coincides with the original straight edge, as in Fig. 123.

The optic center of a concave lens is found in the same way as the center of a convex lens.

Position of Optic Center.—Unless otherwise ordered, the optic center of a lens should be placed as near as possible to

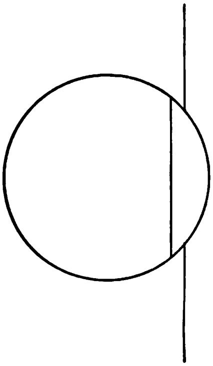


FIG. 125.

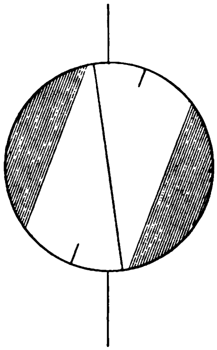


FIG. 126.

the anterior principal focus of the eye (see Cardinal Points, page 98).

A Convex Cylinder.—When a convex cylinder is moved in front of the eye in the direction of its axis, objects looked at do not change their positions; but when the lens is moved in the direction opposite to its axis, the movement of the object is the same as that of a convex sphere. Looking at a straight edge through a convex cylinder, and rotating it, has the effect of displacing away from its axis that portion of the straight edge seen through the lens (see Fig. 126).

A Concave Cylinder.—When a concave cylinder is moved in front of the eye in the direction of its axis, objects looked at do

not change their positions; but when the lens is moved in the direction opposite to its axis, the movement of the object is the same as that of a concave sphere. Looking at a straight line through a concave cylinder, and rotating it, has the effect of displacing toward its axis that portion of the straight line seen through the lens (see Fig. 127). A circle viewed through a strong concave cylinder appears as an oval with its long diameter corresponding to its axis (see Fig. 128). A circle viewed through a strong convex cylinder appears as an oval with its long diameter opposite to its axis. In place of using a straight line or straight edge to find the optic center of a sphere or axis

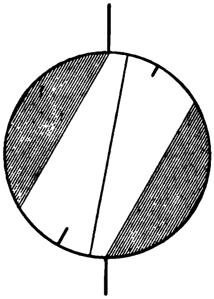


FIG. 127.

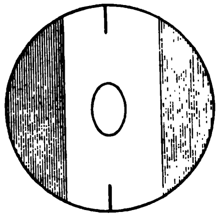


FIG. 128.

of a cylinder, two lines at right angles may be substituted (see Fig. 124), or a protractor may be used.

Neutralization of Lenses.—Having determined from the foregoing description what the character of an individual lens may be, then, to neutralize its effect or find out its strength, a lens of opposite character is taken from the trial-case and held in apposition to it, and the two lenses are moved in front of the eye as a distant object is observed. That lens or combination of lenses which stops all apparent movement of the object is the correct neutralizing lens. Spherocylindric lenses are neu-
zed by finding out what sphere will correct one meridian
what sphere will correct or neutralize the opposite meridian;

for example, if a -2 S. stops all movement in one meridian and -3 S. stops all movement in the other meridian, then the lens being neutralized will be $+2$ S. combined with a $+1$ cyl. Or after a sphere neutralizes one meridian, a cylinder may be combined until the other meridian is neutralized.

CHAPTER VI

THE EYE.—THE STANDARD EYE.—THE CARDINAL POINTS.—VISUAL ANGLE.—MINIMUM VISUAL ANGLE.—STANDARD ACUTENESS OF VISION.—SIZE OF RETINAL IMAGE.—ACCOMMODATION.—MECHANISM OF ACCOMMODATION.—FAR AND NEAR POINTS.—DETERMINATION OF DISTANT VISION AND NEAR POINT.—AMPLITUDE OF ACCOMMODATION.—CONVERGENCE.—ANGLE GAMMA.—ANGLE ALPHA

The Eye.—While the eye is considered as the organ of vision, yet its function is to form upon its retina an inverted image of any object looked at; and if the retinal image is distinct, the object will appear distinct; if the retinal image is blurred, the object will appear blurred. By means of the optic nerve and tract the retinal impression or image is placed in communication with the brain, which interprets the image and completes the visual act.

The Standard Eye.—For purposes of exact calculations it has been found necessary to project a standard or schematic eye, whose nodal point (optic center) shall be 7 mm. back of the anterior surface of the cornea and 15 mm. from the fovea (Helmholtz). Allowing 1 mm. for the thickness of the choroid and sclera, such an eye would have an anteroposterior measurement of about 23 mm. Parallel rays of light passing into such an eye in a state of rest would focus on the macula.

Cardinal Points (Fig. 129).—Images formed upon the retina are the result of refraction by three refracting surfaces and three refracting media. The refracting surfaces are the *anterior surface* of the cornea and the anterior and posterior sur-

faces of the crystalline lens. The refracting media are the cornea (and aqueous humor forming a convex lens), the crystalline lens, and the vitreous humor. These refracting surfaces and media represent a compound dioptric system, centered upon the optic or principal axis; *i.e.*, a line drawn from the pole of the cornea to a point between the nerve and fovea.

On the principal axis are situated the anterior and posterior principal foci (see page 59), the anterior and posterior nodal points, and the anterior and posterior principal points. The anterior principal focus is situated upon the optic axis 13.745+ mm. in front of the corneal apex. The posterior principal focus is situated 15.61+ mm. back of the posterior surface of

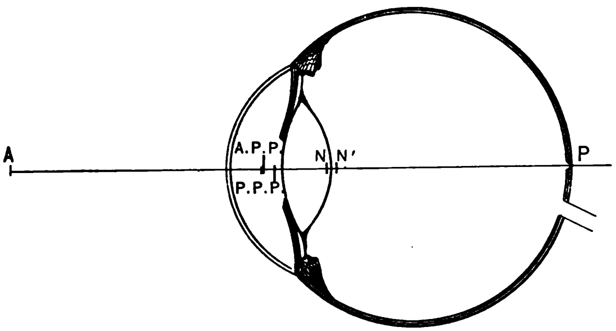


FIG. 129.

the lens. The nodal points are situated about 7 mm. back of the cornea, and correspond approximately to the optic center of this compound refracting system; and as they are so close together, they are considered as one for all purposes in the study of the formation of images. The first or anterior principal point is situated 1.75 mm. back of the anterior corneal surface, and the second or posterior principal point is situated 2.10 mm. behind the anterior surface of the cornea. The principal points are so closely situated that they are considered as one. The anterior focal distance equals 15.49+ mm. and the posterior focal distance equals 20.71+ mm.

The Visual Angle, or Angle of View.—The visual angle is the angle formed by rays of light from the extremes of an object passing to the nodal point of the eye, this latter being the center of the arc; or the visual angle may be defined as the angle which the object subtends at the nodal point of the compound refracting system of the eye. Rays of light from the extremes of an object directed to the nodal point of the eye pass through unrefracted, and continuing their straight course, fall upon the retina, forming an inverted image of the object (see Fig. 130).

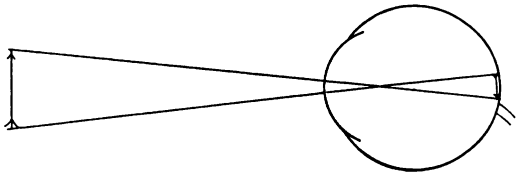


FIG. 130.

The size of the retinal image depends upon the size and the distance of the object from the nodal point of the eye. Objects, therefore, which are seen under the same visual angle must have the same sized retinal image (see Fig. 131).

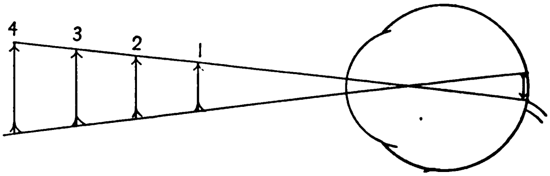


FIG. 131.

If the arrows 1, 2, 3, and 4 represented a child, a man, a tree, and a church, respectively (some distance apart), they would form the same sized retinal images, and if the eye were guided alone by the size of the retinal image, it would judge erroneously; but by experience, distance and comparison of size are brought into judgment.

If, however, arrows 2, 3, and 4 are placed at the side of arrow

1, then their resulting images would increase in size according to the size of their respective visual angles (see Fig. 132).

The nearer an object to the eye, the larger the visual angle and retinal image; the further away an object from the eye, the smaller the visual angle and retinal image. An object to retain the same sized visual angle must, therefore, be made

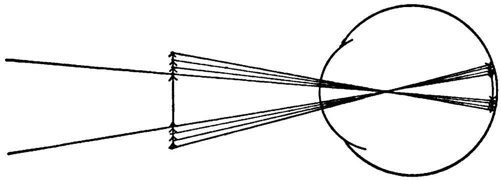


FIG. 132.

larger the further it is removed from the eye; this is demonstrated in Fig. 131, where arrow 1, to be seen under the same visual angle which it has at present, would have to be as large as arrow 4, at the distance of arrow 4.

Minimum Visual Angle.—This is the smallest visual angle in which a standard eye can still recognize an object and give it a name; this angle is also spoken of as the limiting angle of

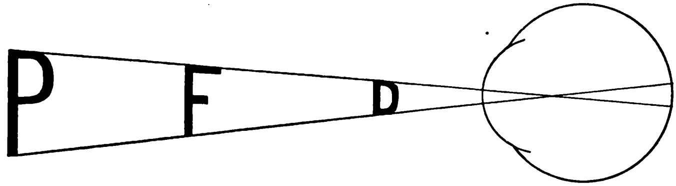


FIG. 133.

vision. In Fig. 133, for example, the letter D at a distance of 6 meters is recognized as the letter D: it is plainly seen; but if placed beyond 6 meters, it would form a smaller visual angle, and could not with certainty be called D.

To be seen at a distance of 12 meters and still occupy this same visual angle, D would have to be made twice as large—*i.e.*, the size of F; and to be seen at 24 meters, it would have to be

four times its present size, or the size of P. Thus, while the letter D, seen clearly at 6 meters, would have to be made proportionately larger as it is removed from the eye, then to occupy the same visual angle it would have to be made smaller if brought closer to the eye and kept within this limiting angle. In Fig. 133 D, F, and P can be seen closer to the eye than their respective distances call for; but the purpose is to find the *greatest* distance from the eye at which they can be seen, as this represents the maximum acuteness of vision, or maximum sharpness of sight.

Standard Acuteness of Vision.—As it was necessary for purposes of calculation to have a standard or emmetropic eye, so it is essential to have a standard acuteness of vision which will be consistent with the standard or emmetropic eye, and thus have some method of recording numerically any departure from this standard visual condition.

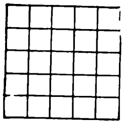


FIG. 134.

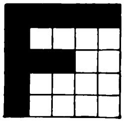


FIG. 135.

The standard acuteness of vision is the power of the eye to distinguish letters and characters occupying a square that is 5′ of arc each way (see Fig. 134). Every letter is, therefore, so proportioned that it will measure just 5′ in the vertical and horizontal meridians, and be reducible to 25 parts or squares each measuring 1′ vertically and horizontally[1] (see Fig. 134).

Figure 135 shows the letter F drawn in a square of 25′, and each stroke of the letter, and space between the strokes, measuring just 1′ of arc. As the tangent of the angle of 5′[2] is expressed by the decimal 0.001454, then to calculate the size of any letter or character which should be seen clearly and distinctly by the standard eye at a certain definite distance, it is necessary to multiply the distance in millimeters by this tangent of the angle

[1] There are two letters in the alphabet which are exceptions to this rule, L and O. L can be seen under an angle of 2′ and O can be seen under an angle of 3′.

[2] *Vegas' tables.*

of 5′. Letters or characters made on this scale are called standard letters. For example, letters to be seen under an angle of 5′ at a distance of 1 meter (1000 mm.) would have to be 1.454 mm. square (1000 × 0.001454). At 6 meters (6000 × 0.001454) = 8.7 mm., etc.

Size of Retinal Images.—The size of the retinal image depends upon two factors—the size of the object itself and its distance from the nodal point. In the standard eye it has been stated that the nodal point was 7 mm. back of the cornea and 15 mm. in front of the retina; then an object 8.7 mm. square situated 6000 mm. in front of the eye would have a retinal image $^{15}/_{6000}$ of 8.7, or 0.02 + mm., and this is the size of the retinal image in a standard eye, looking at a standard letter at 6 meters distance. A good rule for finding the size of the retinal image is to multiply the height of the object by the distance between nodal point and image and divide this by the distance between nodal point and object. In other words, the size of the retinal image is to the size of the object as their respective distances from the nodal point.

FIG. 136.

Refraction in ophthalmology has most to do with eyes whose measurements are not according to the standard or emmetropic condition, and which have their retinas closer to or further from the nodal point than 15 mm. (spoken of as ametropic). The retinal images in such eyes will be smaller in the former and larger in the latter (see Fig. 136).

Accommodation.—This may be described as the power of the eye to focus rays of light upon its retina from different distances at different times. In other words, the eye cannot focus rays of light upon its retina from different points at one and the same time. For example, the point of a pencil held 6 in. in front of the eye is not seen clearly (is hazy) as the eye

looks at a printed page 13 in. beyond; and, *vice versa*, the printed page is not seen distinctly if the point of the pencil is looked at. In the study of convex lenses it was noticed that when an object was brought closer than infinity, the focus of the lens was correspondingly lengthened; and so, in the photographer's camera, to keep the focus on the ground-glass or sensitive plate as the object is brought toward the camera, it is necessary to push the lens forward by means of the accordion plaits; but the human eye does not lengthen or shorten in this way. Normally, the eyeball is inextensible, and to accomplish this same purpose the ciliary muscle must contract, causing the crystalline lens to become more convex, and thus keep the rays of light entering the eye at a focus upon the fovea.

The Mechanism of Accommodation.—To appreciate this, it is necessary to understand something of the anatomy of the ciliary body, of which the ciliary muscle is a part. The ciliary body is circular in form and occupies a small (3 mm.) area in the eye, just beneath the sclera, at its corneal junction (see Fig. 129). In section the ciliary body is triangular in shape, the base of the triangle measuring about 0.8 mm. and facing toward the anterior chamber, the apex of the triangle extending backward beneath the sclerotic. The ciliary body lies in apposition to the sclera, but has only a very minute attachment to it, at the sclerocorneal junction, called the ligamentum annulare, or pectinatum. That portion of the ciliary body lying next to the hyaloid membrane of the vitreous humor is composed of folds, known as the ciliary processes, seventy or more in number.

A portion of the ciliary body is composed of muscular fibers disposed in flat bundles, which interlace with each other, forming a sort of plexus, and called the ciliary muscle. This muscle, by the character of its fibers, has been subdivided into three parts: (1) Meridional; (2) radiating; and (3) circular or sphincter fibers. The meridional are the longest, lie next to the sclerotic in lamellæ, parallel with it, and pass back to join the choroid coat of the eye, forming what is known as the tensor choroideæ,

or muscle of Brücke or Bowman. The radiating fibers are fan-shaped, few in number, and scattered through the ciliary body. The circular or sphincter fibers—also called annular—are sometimes referred to as the muscle of Müller, or compressor lentis, and are the most important fibers in the consideration of accommodation; they form a sphincter ring concentric with the equator of the lens. Attached to the ciliary body, well forward on its inner side, near the base of the triangle, is the ligament of the lens (zonule of Zinn), and it in turn sends fibers to the anterior and posterior capsule of the lens. This ligament of the lens occupies an interval of about 0.5 mm. between the ciliary body and the periphery of the lens, and is a *constant* factor in all conditions of the healthy eye.

During the act of accommodation the following changes take place in the eye:

1. The ciliary muscle contracts.

2. The ciliary muscle (sphincter), by contracting, makes a smaller circle.

3. The tensor choroideæ draws slightly upon the choroid (compressing somewhat the vitreous body), and these two sets of fibers, sphincter and meridional, acting together, relax the ligament of the lens, with the result that—

4. The lens fibers, no longer held in check, become relaxed, and by their own inherent quality (elasticity) allow the lens to become more convex, especially on its anterior surface.

5. The anterior surface of the lens being made more convex, approaches the cornea.

6. The posterior surface of the lens becomes slightly more convex, but retains its position at the pole.

7. The lens axis is lengthened, but the equatorial diameter diminishes, thus keeping up the uniform interval between the equator of the lens and the ciliary body, as previously referred to. *The lens does not increase in volume.*

8. The anterior chamber becomes slightly shallower at the center and deeper in the periphery.

9. That portion of the iris resting upon the anterior capsule of the lens is pushed forward, especially at its pupillary edge.

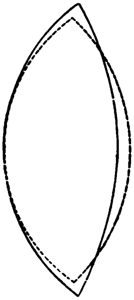


Fig. 137.

10. The iris contracts, producing a smaller pupil; but it must be remembered that contraction of the iris is not an essential condition in accommodation. The shape of the cornea is not changed during contraction of the ciliary muscle.

The following table shows the comparative measurements of a lens at rest and during the height of accommodation in a healthy emmetropic eye of 10 years. The dotted lines in Fig. 137 indicate the changes in the shape of the lens at the height of accommodation.

	At rest	Height of accommodation
Radius of curvature of anterior surface of lens......	10.0 mm.	6.0 mm.
Radius of curvature of posterior surface of lens.....	6.0 mm.	5.5 mm.
Distance from anterior surface of cornea to anterior surface of lens..............................	3.6 mm.	3.2 mm.
Anteroposterior diameter, on axis.................	3.6 mm.	4.0 mm.
Distance from anterior surface of cornea to posterior surface of lens..............................	7.2 mm.	7.2 mm.
Equatorial diameter.............................	8.7 mm.	8.2 mm.

Far Point.—Latin, *punctum remotum;* abbreviated p. r. or r. The far point may be defined as the greatest distance at which an eye has maximum sharpness of sight, or the most remote point at which the eye, in a state of rest, has maximum acuity of vision. **Infinity.**—Besides the definition on page 4, this may be described as the far point of an emmetropic eye. **Parallelism.**—Distance that cannot be measured.

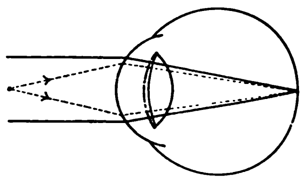


Fig. 138.

The standard or emmetropic eye, when looking at distant objects, receives parallel rays of light at a focus upon its fovea (Fig. 138), and also emits parallel rays; under these conditions

the ciliary muscle is not acting, the eye is in a condition of complete repose, of rest, of minimum refraction, and is adapted for its far point.

Near Point.—Latin, *punctum proximum;* abbreviated p. p. or p. This may be defined as the nearest point at which an eye has maximum sharpness of sight, or the nearest point to the eye at which it has distinct vision, the lens is in the condition of greatest convexity, of maximum refraction (Fig. 138).

Amplitude of Accommodation.—This is also called the **range**[1] or **power**[2] **of accommodation,** and may be defined as the difference between the refraction of the eye in a state of rest (or adapted for its far point) and in a condition of maximum refraction, or adapted for its near point. For example, an emmetropic eye has infinity for its far point, and if 10 cm. distance is its near point, then the difference between the lens adapted for infinity and 10 cm. will be 10 D., as 10 cm. represents the focal length of 10 D. In other words, there is no accommodation used for infinity, but there is an accommodation of 10 D. for the near point, which is the amplitude or power of accommodation. The emmetropic eye in a state of accommodation adds on to the anterior surface of its lens what is equivalent to a convex meniscus. Figure 138 shows an emmetropic eye at rest receiving parallel rays of light at a focus upon its retina, and it also shows the same eye in its maximum state of accommodation for a point 10 cm. distant; the broken line representing what is equivalent to a convex meniscus, added to the anterior surface of its lens.

When the distance of the near point is known in inches or centimeters, the equivalent in diopters is found by dividing 40 by the near point in inches, or by dividing 100 by the near point in centimeters. The near point being 10 cm., or 4 in. (10 into 100 or 4 into 40) the amount of accommodation will be 10 D.

[1] Range applies to the space between the far and near points.

[2] Power applies to the force or strength or diopters necessary to change the refraction from the far to the near point.

In the study of healthy emmetropic eyes it has been found that the power of accommodation gradually diminishes as the eye passes from youth to old age. This is the result of one or more changes: the lens fibers lose their elasticity, becoming sclerosed, or the ciliary muscle grows weak, or both of these changes may exist together. Rarely the cornea may flatten. A knowledge of the power of accommodation is absolutely essential, so that any variations from the standard condition may be noted. The following table gives the ages from 10 to 75 years, respectively, with five-year intervals, and the near point consistent with each, as also the amplitude of accommodation for each period.

Year	Near point	Amplitude in diopters	Year	Near point	Amplitude in diopters
10	7.0 cm.	14.0	45	28 cm.	3.50
15	8.5 cm.	12.0	50	40 cm.	2.50
20	10.0 cm.	10.0	55	55 cm.	1.75
25	12.0 cm.	8.5	60	100 cm.	1.00
30	14.0 cm.	7.0	65	133 cm.	0.75
35	18.0 cm.	5.5	70	400 cm.	0.25
40	22.0 cm.	4.5	75	∞	

This table of near points applies *only* to emmetropic eyes or those eyes which are made emmetropic by the adjustment of correcting lenses. The table of amplitudes, however, is the same, with a few exceptions, for all eyes of whatever degree or amount of ametropia.

A patient whose age might be between any of the five-year periods given in the table, would have the near point between the corresponding near points; for example, a patient of 22 years would have a near point at 11 cm.

For a better appreciation of the amplitude of accommodation it is necessary to understand the two forms of eyes already referred to in Fig. 136.

First, the eye which has its retina closer to its refractive media than the principal focus; such an eye is spoken of as a short or hyperopic eye (H in Fig. 136). (Hyperopia: Greek, *ὑπέρ, over; and ὤψ*, eye.)

This eye in a state of rest (under the influence of atropin) will emit divergent rays of light, and is, therefore, in a condition to receive only convergent rays of light at focus upon its retina (see Fig. 139). Parallel rays would not focus upon the retina of such an eye, but, if possible, would focus back of the retina.

Second, the eye which has its retina beyond the principal focus of its dioptric media (M in Fig. 136); such an eye is spoken of as a long or myopic eye (Greek, μύειν, to close; ὤψ, eye). This eye always emits convergent rays, and is, therefore, in a state to receive divergent rays of light at a focus upon its retina (see Fig. 140). Parallel rays would not focus upon the retina of a myopic eye, but in the vitreous in front of the retina.

The Far Point of a Hyperopic Eye.—This must necessarily be negative (see Fig. 139), and is found by projecting the diver-

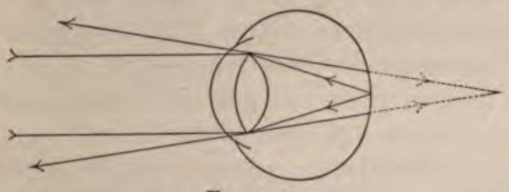


FIG. 139.

gent emergent rays backward to the imaginary point behind the retina from which they appear to have diverged. A hyperopic eye, to receive parallel rays of light at a focus upon its retina, must, therefore, accommodate, and the amount of accommodation thus exerted will remove the near point just that much from the eye as compared with an emmetropic eye. For example, according to the table of amplitudes just given, an eye at 20 years has 10 D. of accommodation, but if it uses 2 D. of this to make rays of light parallel, then it only has 8 D. left to accommodate inside of infinity, with the result that the near point comes to only (8 into 100) 12.5 cm.; this hyperopic eye, therefore, at 20 years of age has a near point like that of an emmetropic eye at 25 years of age; or if an eye which is 25 years old

has an amplitude of accommodation of 8.5 D., and has to use 4.5 D. for infinity vision, it would have (4 into 100) a near point of 25 cm. (10 in.) and be like an emmetropic eye 43 years of age.

The Near Point of a Hyperopic Eye.—From the description just given it will be seen at once that the near point in hyperopic eyes is always *further* removed than in the emmetropic eye for a corresponding age, and that the near point depends upon the amount of accommodation that is left after the eye has accommodated for infinity.

The Far Point of a Myopic Eye.—This is always positive and situated some place inside of infinity. It is found by uniting the convergent emergent rays (see Fig. 140).

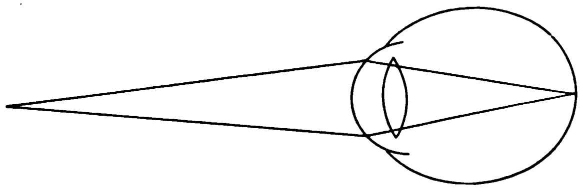


FIG. 140.

The far point of a myopic eye is the result of its strong refracting power or the distance of its retina beyond the principal focus of its dioptric media. The retina and far point of a myopic eye are conjugate foci (see Fig. 140). The myopic far point is equivalent to just that much refraction in excess of the emmetropic eye. An emmetropic eye under the influence of atropin would require a +2 S. placed in front of it to make rays of light focus upon its retina from a distance of 50 cm., and rays of light from the retina of this eye with a +2 S. in front of it would focus at 50 cm. This eye, then, equals a myopic eye of 2 D. This myopic eye would have a far point of 50 cm. Where the rays of light meet as they come from a myopic eye in a state of rest is its far point.

The Near Point of a Myopic Eye.—This is always closer than *in the emmetropic* eye for a corresponding age, and depends

upon the distance of its far point. For example, an eye at 25 years has 8.5 D. amplitude of accommodation, but if it has a far point of 70 cm., then its near point will be represented by 8.5 D. and 70 cm.; *i.e.*, 1.5 D., which would equal 10 D., or a near point of 10 cm. The following table gives the comparative near points in cm. in an emmetropic eye, a hyperopic eye of 2 D., and a myopic eye of 2 D.:

Age	10	15	20	25	30	35	40	45	50	55	60	65	70	75
Emmetropia, p. p......	7.0	8.3	10.0	12	14	18.0	22.0	28	40	55	100	113	400	∞
2 D. Hyperopia, p. p...	8.3	10.0	12.5	16	20	28.5	40.0	66	200	∞	—	—	—	
2 D. Myopia, p. p.....	6.0	7.0	8.3	10	11	13.0	15.3	18	22	25	33	36	44	50

Determining the Vision.—This may be considered as the method of finding out what an eye can see without any lenses placed in front of it; in other words, determining the vision may be defined as ascertaining the seeing quality of the unrefracted eye. The refraction of an eye should never be confounded with the visual quantity, as refraction applies to the refractive media; for example, an emmetropic eye with a hemorrhage at the fovea would be practically without visual quantity, and yet its refraction or refractive condition would be standard. The most acute vision is at the fovea and the region immediately surrounding it, but this sensibility diminishes as the fovea is departed from and the peripheral portion of the retina approached; this is due to the fact that the cones are 0.002 of a mm. in diameter at the macula, and not numerous in the forepart of the eye-ground. In fact, there are very few cones in the forepart of the retina, as this portion of the retina is composed mostly of rods and is used mostly for form seeing.

Test-type or Test-letters for Distant Vision.—To determine the vision we employ cards on which are engraved test-type or letters of various sizes, constructed so that each letter subtends an angle of 5′, as suggested by Snellen, and described on page

102. Figure 141 shows such cards of test-letters, reduced in size. The Roman characters just above the top of the letters indicate the distance in meters that the letters should be seen by the standard eye, and the little figures at the left of the letters indicate the equivalent distance in English feet. The top letter should be seen at 60 meters, and the bottom letter at 3 meters; the intervening letters are to be seen at the respective distances indicated. As it is not unusual to find eyes that have a seeing quantity better than that obtained with Snellen's

Fig. 141.—Randall's test-letters. Block letters in black on cream-colored cards.

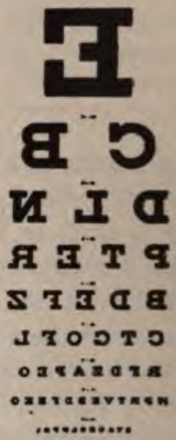


Fig. 142.

type (reversed) (Fig. 142) constructed on the angle of 5′, Dr. James Wallace has constructed letters which subtend an angle of only 4′. Such a card is shown in Fig. 143, and has a large field of usefulness. While test-cards are usually white or cream-colored, with black letters, Gould has white letters constructed on black cards (see Fig. 145). As white stimulates the retina and black does not, it will be recognized at once that in one instance the card, and in the other the letters, produce the retinal stimulation. The white letters seem to stand out from the black card almost as if they were embossed, giving a clear-

cut edge and most soothing effect to the eye under examination. To avoid reflection, this card should be hung at an angle.

"There is a general tendency on the part of railroads to adopt signs with white letters on a black background, not realizing that the black letter on a white background is easier to read and can be seen at a greater distance. This follows in an interesting way from the structure of the retina of the eye.

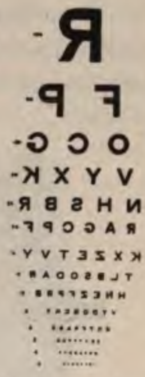


FIG. 143.—Four minute letters of Dr. J. Wallace. This card is constructed principally for reflection purposes (see Fig. 7).

FIG. 144.

The impression of a letter at the limit of vision is received on the ends of a small bundle of nerves which convey to the brain a sort of mosaic impression. A nerve can only transmit to the brain information as to whether or not a ray of light is falling upon it and when a nerve is partly in the light and partly in darkness the sensation is the same as though all of it was in the light. It follows, therefore, that all nerves on the dividing edge between any black and white area transmit the sensation of light so that all white lines and white areas appear wider and all black lines and black areas appear narrower than they really are. Two black letters in an illustration grow thinner at the limit of vision and are still recognizable, while at the same distance the two white letters grow thicker and cannot be distinguished.

There are circumstances when it is necessary to use white letters, but in such cases legibility will be improved if they are made with a thin stroke and strongly lighted. Black letters are more distinct if made with a heavy stroke."—S. S. BALCH in *Scientific American*.

For aliens who do not know the English letters, and for illiterates, a special card has been made, known as the illiterate or "dummy" card, with characters consisting of lines shaped like the capital letter "E," and made to conform to the 5′ angle. As these letters are variously pointed, the patient is asked to tell, or indicate with his finger or fingers, the direction in which the prongs of the "E" point: up, down, to the right or left. This illiterate card (see Fig. 144) is much to be preferred to the German, Hebrew, and "figure" cards occasionally displayed in clinics.

FIG. 144A.—Author's test objects or kindergarten card for children and illiterates.

Kindergarten Card.—To keep the attention of children who do not know the alphabet, or who attend a Kindergarten school, the author has prepared a card of test objects as shown in Fig. 144A. These objects have been drawn up to the angle of 5′, though some of their component parts do not measure up to 1′.

Selection of Test-cards.—The surgeon should have several of these in duplicate with the order of the letters changed (Figs. 141, 145), as patients not infrequently and unintentionally commit them to memory. Care should be exercised in the selection of test-cards, to see that each letter on the card measures up to the standard square of 5′, as many of the A's and R's and N's (Fig. 142), etc., on the old cards as seen in the shops measure 6′ and 7′ horizontally. It is a matter of choice with the surgeon whether to use test-cards with the block or Gothic letters. It *is well to have* both.

Method of Procedure.—The test-card should be hung on the wall with its $\frac{\text{VI}}{\text{VI}}$ line 5 or 6 in. below the level of the patient's eyes, and illuminated by means of reflected artificial light. This is always a certain quantity, whereas daylight is too variable and not to be depended upon. The patient should be placed with his back toward any bright light, and at a distance of 6 meters from the card. Sometimes the surgeon's office is not 6 meters long, and this distance must be obtained by using diagonal

FIG. 145.—Gould's test-letters. Gothic letters in white on black cards.

corners of the room or by using a plane plate-glass mirror and a specially prepared test-card with reversed letters (see Figs. 142 and 143), the card being hung as many meters in front of the mirror as will make 6 meters when added to the length of the office. Each eye should be tested separately, the fellow-eye being shielded or covered by a card or blinder (Fig. 146), or opaque disc (Fig. 147) held in front of it or placed in the trial-frame. The eye should never be held shut, and any pressure upon the eyeball must be avoided. While a distance of 6 meters is always to be preferred, yet if this cannot be obtained

the surgeon may use a distance of 4 meters, but never less than this.

A distance of 20 ft., while not always attainable in an office, may be secured out of the office window as illustrated in Figs. 148, 149, and 150, giving ranges, on the side fence of 20 ft., 66 ft. at the gate, and 200 ft. in the neighbor's window. This shows the possibilities for long range vision between houses in a city office. Fortunately, in this instance, the morning sun

FIG. 146.

answers all the purposes of illumination. On rainy, snowy, and cloudy days these cards cannot be used to advantage. The card in the distant window is protected from the elements and those in the side yard are also protected in their frames by ¼-in. plate glass; in fact, there is plate glass on each side of each card and the card can easily be slipped out from below and another put in its place at any time.

The record of the visual acuity is usually made in the form of *fractions, using* Arabic or Roman notation; figures usually indi-

cate feet, and Roman letters usually signify meters, though there is no fixed rule for this. However expressed, the denominator indicates the size of the type which the eye reads, at the distance indicated by the numerator. For example, if at VI meters the eye reads the line of letters marked VI, then the record would be $\frac{VI}{VI}$. This would be $20/20$ if the numerator and denominator were expressed in feet. If the eye, at a distance of VI meters, reads only the letters on the XII line, then the record would be $\frac{VI}{XII}$, or $20/40$ (ft.). If the top letter was the only one recognized at the distance of VI meters, then the record would be $\frac{VI}{LX}$ (meters), or $20/200$ (ft.). If the eye reads the VI line, miscalling two letters, then the record could be made in one of four ways, each indicating the same thing. $\frac{VI}{VI}$?? (one question mark for each mis-called letter), or "$\frac{VI}{VI}$ partly" would indicate that the eye saw $\frac{VI}{VI}$, but not each letter correctly. This way of making the record is not so explicit as that with the question marks. Or, $\frac{VI}{VIISS}$ + would mean that the eye saw all of $\frac{VI}{VIISS}$ and some of the letters of $\frac{VI}{VI}$; but this, too, is not so definite as the first record and the one recommended. Or, $\frac{VI}{VI}-2$ would mean that the eye saw the $\frac{VI}{VI}$ line minus two letters.

FIG. 147.

If the eye cannot recognize any letter on the card at the distance of VI meters, then the card should be brought toward the patient, or the patient told to approach the card, until the eye can *just* make out the top letter and no more. If this is seen at IV meters, then the record will be $\frac{IV}{LX}$; if at 1 meter, the record would be $\frac{I}{LX}$, etc. While it has been stated that the visual record is usually made in the form of common fractions,

as just described, yet there are some who prefer to make the record in the form of decimals; namely, a vision of $\frac{VI}{VI}$ would be 1.0, a vision of $\frac{VI}{XII}$ would be 0.50, or a vision of $\frac{VI}{XXIV}$ would be

FIG. 148.

0.25, or a vision of $\frac{VI}{LX}$ would be 0.1. Most authorities prefer to make their records in the form of common fractions.

In some instances the eye may not be able to distinguish any *letter on the card*, no matter how close it may be brought to the

eye, and in such a case the vision is tested by holding the outstretched fingers between the patient's eye and a bright light (a window); and a note is made of the greatest distance at which

FIG. 149.

the eye can count fingers; if at 10 in., the record would be "fingers counted at 10 in.," or whatever the distance may be. This ability to recognize form is spoken of as "qualitative light perception." Eyes that are not able to recognize form

may still be able to distinguish light from darkness, and this ability is tested by alternately covering and uncovering the eye as it faces a light, or as light is reflected into it from a mirror.

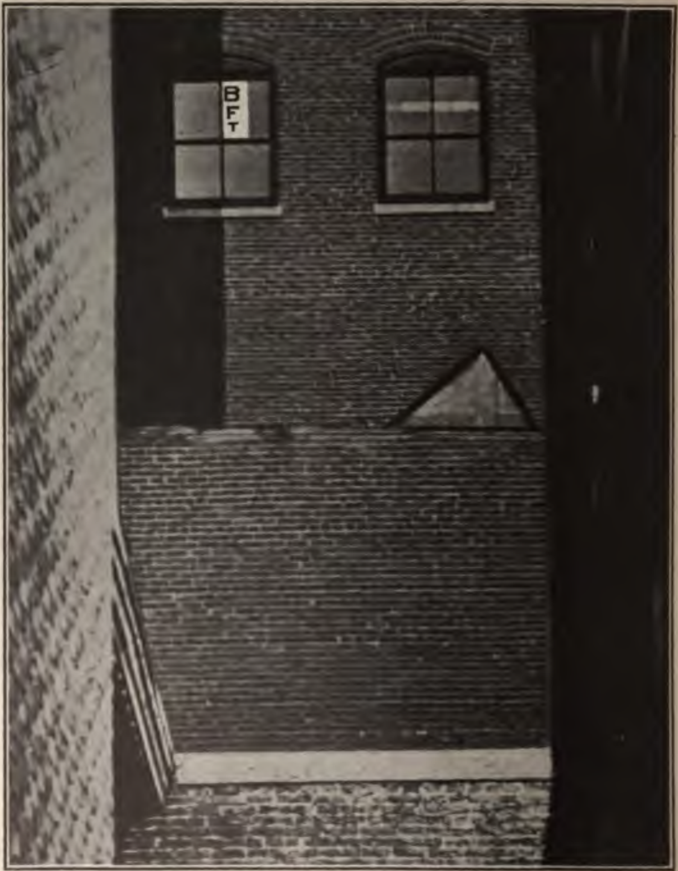


FIG. 150.

If "qualitative light perception" is present, the vision is recorded L. P., which means "light perception," or the record may be made L. & S., which means practically the same thing, "light *and shade*."

Determining the Near Point.—Having obtained and recorded the distant vision of an unrefracted eye, it is well to also find out and note what is the nearest point to the eye at which small type can be made out; this is spoken of as determining the near point.

Test-type or Test-letters for Near Vision.—To determine the near point, we employ cards on which are printed or engraved words or sentences, or a series of letters, so that each letter in each word or sentence shall subtend an angle of 5′, at a given distance from the standard eye; for instance, letters that are to be seen at 1 meter and occupy the angle of 5′, must be 1.454 mm. square; letters that are to be seen at half a meter distance must be 0.727 mm. square, etc. Most of the "near" cards in the market are very defective in this respect, and the near types of Jaeger are becoming obsolete, as they are not standard letters, but merely represent the various fonts of printers' type. The writer's card is one of Gothic type, as shown in Fig. 151. Another card in block letters is shown in Fig. 152. Above each series of letters is marked the greatest distance (D) at which the respective letters can be seen; these distances vary from 0.25 to 2 meters (25 to 200 cm.), which are ample for all purposes in estimating the near point.

Method of Procedure to Find the Near Point.—The patient is seated so that the light entering the room will come over his shoulder and fall upon the card of test-type held in front of him. The surgeon, to one side of the patient, holds the card in one hand and a meter stick in the other, the eye which is not being tested is covered with a card or blinder, and the patient is told to select the *smallest* type on the card which he can read or spell, and as he continues to do so (aloud), the surgeon gradually approaches the card to the eye until the patient says that the letters commence to grow "hazy" and he can scarcely decipher them; or another way is to hold the card close to the patient's eye and gradually withdraw it until he can just recognize the letters; when this point is reached, *the distance from the eye to*

the card is measured with the meter stick, and this distance, as also the size of the type which was read, is carefully recorded. For example, the patient selecting the type marked 0.50 D. and

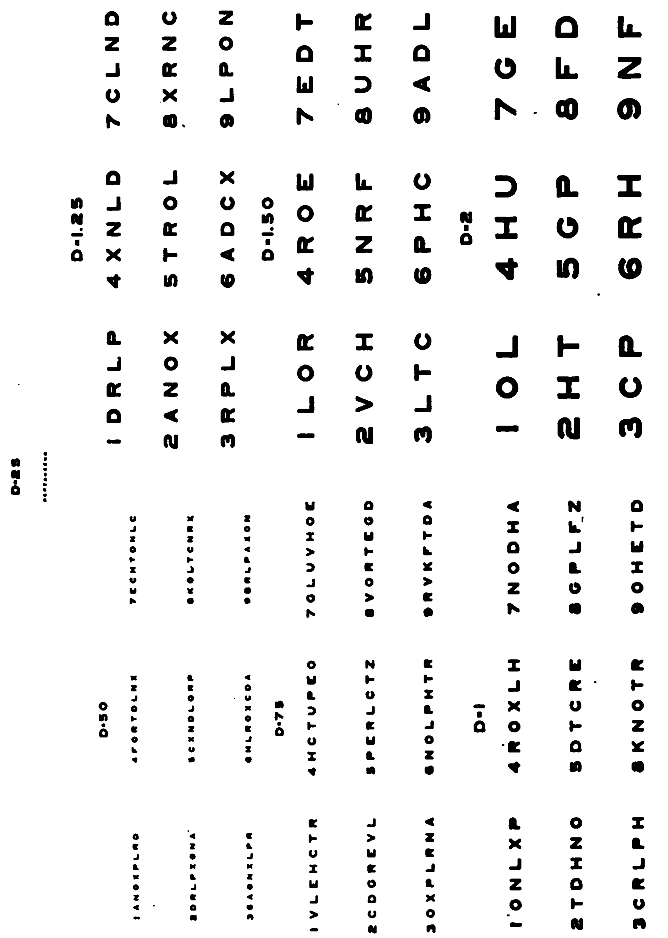


Fig. 151.

is able to read it as close as 8 cm. and no closer, the record will be "near point equals type 0.50 D. at 8 cm.;" or abbreviated, *would be "type* 0.50 D. = 8 cm."

In some instances the patient may not be able to read any of the near type without the aid of a glass, and if so, it will be neces-

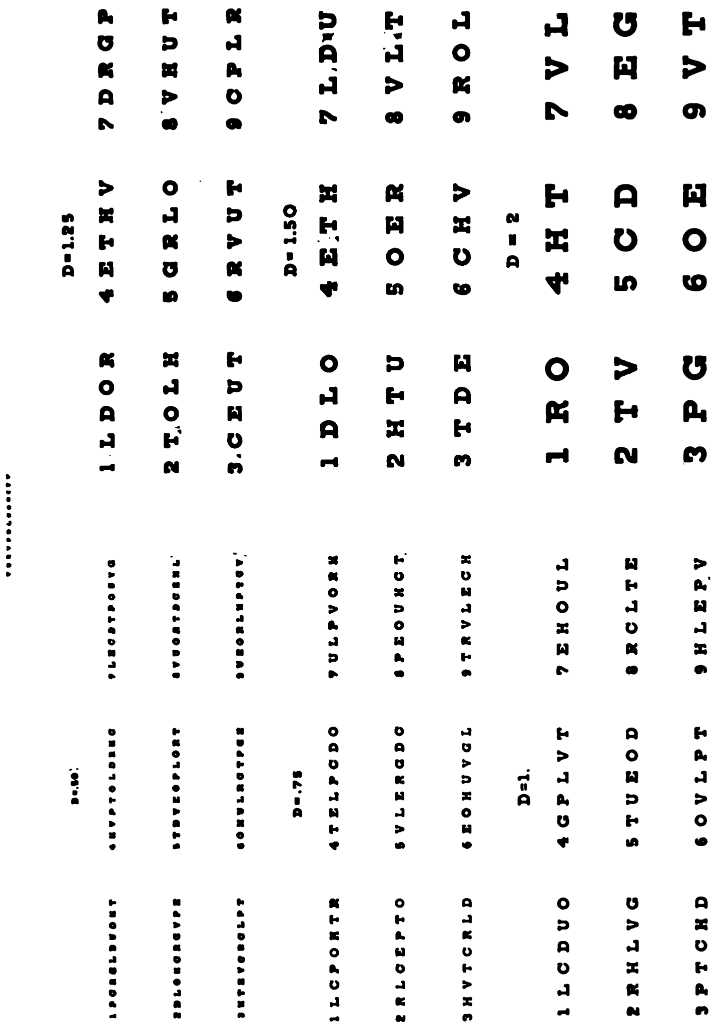


FIG. 152.

sary to place a plus sphere in front of the eye to assist in finding the near point; for example, if a +2 S. was employed, then the

record might be "near point equals type 0.50 D. at 12 cm. with +2 S.," or "+2 S.=type 0.50 D. at 12 cm."

Convergence.—*Con*, "together," and *vergere*, "to turn;" literally, turning together. This is the power of the internal recti muscles (especially) to turn the eyes toward the median line; to "fix" an object closer than infinity. Standard eyes, when looking at an object at a distance of 6 meters or more, are not supposed to converge; the visual lines are spoken of as parallel and the power of convergence is in a state of repose. The angle which the visual line makes in turning from infinity (∝) to a near point is called the angle of convergence, and the angle which is formed at 1 meter distance by the visual axis with the

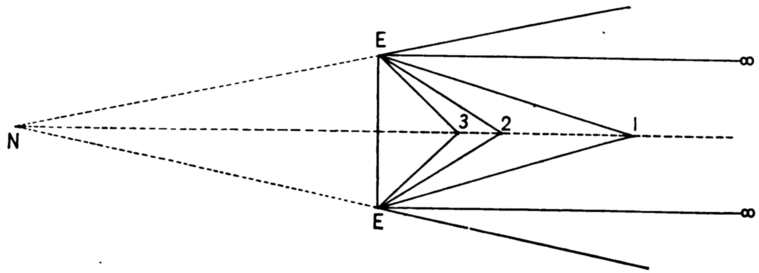


FIG. 153.

median line is called the meter angle, or the unit of the angle of convergence (see 1, in Fig. 153).

If the visual line meets the median plane at ½ of a meter, it has then 2-meter angles of convergence; at ¼ of a meter, 4-meter angles of convergence, etc. Or 5-meter angles means that the eye is converging to a point ⅕ of a meter distant.

The size of the meter angle varies; it is not the same in all individuals; in fact, the meter angle is smaller in children than in adults, as a rule, on account of the shorter interocular distance. In children this distance is about 50 mm., whereas in adults it is, on the average, 60 or 64 mm.

While standard eyes, to see a point 1 meter distant would *converge just 1* meter angle, they would also accommodate just

1 diopter; to see a point at 1/3 of a meter they would converge just 3 meter angles, and at the same time would accommodate 3 diopters, etc., thus showing how intimately the powers of convergence and accommodation are linked together, though it is possible to converge without accommodation (see Presbyopia) or to accommodate without convergence (paralysis of the interni).

Far and Near Points of Convergence.—Just as we have a far and a near point of accommodation, we also have a far and a near point of convergence. The far point of convergence is the point to which the visual lines are directed when convergence is at rest, or at a minimum. The near point of convergence is the point to which the visual lines are directed when the eyes are turned inward to their utmost degree.

Infinity, or parallelism, is the position of the visual lines in the standard eyes in a state of rest (E $\propto$, in Fig. 153). Visual lines that diverge in a state of rest can meet only by being projected backward, and, therefore, meet at an imaginary point behind the eyes (N, in Fig. 153); convergence is then spoken of as negative, or minus ($-$).

If the visual lines meet in a state of rest, then convergence is spoken of as positive ($+$).

The amplitude of convergence is the distance measured from the far point to the near point of convergence, and is represented by the greatest number of meter angles of convergence which the eyes can exert.

Angle Gamma.—An understanding of what is known as the angle gamma is important, that the observer may understand and appreciate the real or apparent position of the eyes when looking at a near or distant point. Figure 154 shows the line OA (optic axis) and the optic center, or nodal point (N), situated on this line in the posterior part of the crystalline lens (see Frontispiece). The line VM is really a secondary axis to this dioptric system of the eye, and unites the object (V) with the fovea centralis at M; this line is known as the visual line. The

+23 D. An index below the sight-hole of the instrument records the strength of lens that may be in use; minus lenses are usually marked in red and plus lenses in white.

How to Use the Ophthalmoscope.—There are two ways or methods by which the ophthalmoscope may be used—the direct and the indirect.

The Direct Method (see Fig. 158).—Proficiency with the ophthalmoscope does not come except from long and constant practice, and several important matters should receive very careful attention before the student attempts to study the interior of an eye.

The Room.—This should be darkened by drawing the shades or closing the blinds; the darker the room, the better.

The Light.—This should be steady, clear, and bright; a good lamp is suitable, but an Argand burner gives more intense light and is to be preferred, especially if it is placed on an extension bracket that can be raised or lowered and is capable of lateral movement.

Position of Light and Patient.—The light should be several inches to one side and back of the patient, and on a level with the patient's ear, so as to illuminate the outer half of the eye-lashes of the eye to be examined; it may even be well to have the tip of the patient's nose illuminated (Fig. 158).

The patient should be seated in a comfortable chair (without arms), and is instructed to look straight ahead into vacancy, or at a fixed object if necessary, and is only to change the direction of his vision when told to do so. Under no circumstances should the patient be allowed to look at a light, as this will contract the pupil.

For the beginner, it may be well to dilate the patient's pupil with a solution of cocain or homatropin. The student, however, should learn to see into an eye without always using a mydriatic, as an occasional patient objects to the slight inconvenience that results from the drugs mentioned. It may be *stated here that* a weak mydriatic is not dangerous in the

least, and that by its use alone can the lens be uncovered and studied as well as the entire eye-ground.

The Observer.—If the observer has any decided refractive error, he should wear his correcting glasses; the reason for this

Fig. 158.

will be explained later. The observer should be seated at the side of the patient corresponding to the eye he is to examine. Examining the right eye, the observer should be on the patient's right; if the left eye, then on the patient's left.

When examining the right eye, the ophthalmoscope is held in the right hand, before the right eye; and in the left hand, and before the left eye, when examining the left eye. The surgeon's eye should be a little higher than the patient's. Patient and observer should keep both eyes open. The one exception to this is when the patient has a squint, when it

Fig. 159.—Correct position.

will be necessary for him to cover the eye not being examined, and in this way the eye under observation will look straight ahead.

The surgeon holds the ophthalmoscope perpendicularly, so that the sight-hole in the mirror is directly opposite to his pupil and close to his eye. The side of the instrument rests *on the side* of his nose and the upper margin in the hollow of

the brow. The mirror is tilted toward the light. The surgeon's elbow should be at his side, and not form an angle with his body (Figs. 159 and 160).

With these several details carefully executed, the surgeon begins his examination at a distance of about 25 or 30 cm., never closer; and at this distance he reflects the light from the

FIG. 160.—Faulty position.

mirror into the eye and observes a "red glare," which occupies the previously black pupil. This is called the "reflex," and is due to the reflection from the choroidal coat of the eye. The *color* of the reflex varies with the size of the pupil, transparency of the media, the refraction, and the amount of pigment in the eye-ground.

Having obtained the "reflex," it will be well for the beginner to practise keeping the reflected light upon the pupil by chang-

ing his distance, approaching the eye as close as an inch or two; this must be done slowly, and *not* with a rush.

What the Observer Sees.—Having learned to keep the light on the pupil, the next thing is to study the transparency of the media—*i.e.*, to find out if there is any interference with the free entrance and exit of the reflected rays, such as would be caused by opacities in the cornea, lens, lens capsule, or vitreous; and, if present, to note their character and exact location, whether on the visual axis or to one side, etc. The next objective points will be mentioned individually, and with the idea of systematizing the study.

The Optic Nerve.—Also called the disc (disk) or nerve head or papilla.

Color of the Optic Disc.—This has been described as resembling in color the marrow of a healthy bone, or the pink of a shell, etc.; yet this is not by any means a true statement or description, as the apparent color of the nerve is controlled in great part by the surrounding eye-ground—whether this is heavily pigmented or but slightly so, or whether there is an absence of pigment, as in the albino. The student should be ready to make allowances for these contrasts.

The shape of the disc varies: it may appear round, oval, or even irregular in outline. Usually it is a vertical oval.

The vessels on the disc which carry the blood to and from the retina are not of the same caliber, nor do they have the same curves and branches in all eyes or in the same pair of eyes. The central artery may be single or double (if it has branched in the nerve before entering the eye), and enters the eye at the nasal side of the center of the disc.

Approximating the central artery on its temporal side is the retinal vein, which may also be double. The relative normal proportion in size between arteries and veins is generally recognized as about two or three. The veins are usually recognized by their larger size and darker color. At or near *the center of* the disc is often seen a depression, known as the

physiologic cup; this may be shallow or deep; it may have shelving or abrupt edges; it may even be funnel-shaped.

At the bottom of the cupping is frequently seen a gray stippling, the membrana cribrosa, openings in the sclera for the passage of the transparent optic nerve fibers which go to form the retina. Surrounding the disc proper is often seen a narrow white ring; this is sclera, and is known as the scleral ring. Just outside of this ring is frequently seen a ring of pigment; this is called the choroidal ring. In many cases the choroidal ring is not complete, the pigment being quite irregular, or possibly there may be one or more large masses of pigment to the side of the disc; these are not necessarily pathologic.

The retinal arteries and veins, while possessing many anomalies, and while occasionally an artery and vein are seen to twine around each other, usually pursue a uniform course up and down from the disc, and are named accordingly—*i.e.*, upper nasal vein and artery; upper temporal vein and artery; lower nasal artery and vein; lower temporal artery and vein.

The retina itself, in health being transparent, is not seen. The fovea centralis, occupying the center of the macular region, is about two discs' diameter to the temporal side of the disc and slightly below the horizontal meridian. The fovea is recognized because it is a depression, and its edges give a reflex; it is very small, and appears as a bright spot 1 or 2 mm. in diameter. The "macular region" is the part of the eye-ground immediately surrounding the fovea; it contains minute capillaries, but it is impossible, in healthy eyes, to recognize them with the ophthalmoscope.

The Choroid.—This is distinguished by the character of its circulation, the vessels being large, numerous, and flattened, and without the light streak which characterizes the retinal vessels. Pigment areas between the vessels are also diagnostic of this tunic. The choroidal circulation is best studied in the blond or albino, and may be seen in many eyes toward the periphery of the eye-ground.

In the foregoing description of the use of the ophthalmoscope, etc., it is presumed that the instrument has been used without any lens in position, and that the observer's eye and the eye under examination are healthy emmetropic eyes with the accommodation at rest. Figure 161 shows the position of the light, L, the ophthalmoscope, the examiner's and the examined eye under these conditions.

The divergent rays from the light (L) are reflected convergently from the concave mirror, and focusing in the vitreous,

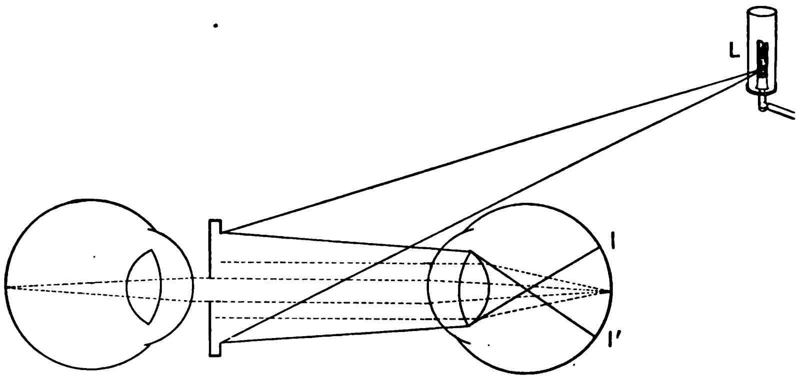


FIG. 161.

they cross and form an area of illumination on the retina at II′. The retina, situated at the principal focus of the dioptric media, naturally projects out from its individual points rays of light which are parallel as they leave the eye; some of these pass through the sight-hole of the mirror and meet upon the retina of the observer's emmetropic eye.

There are two very important points which must be considered when using the ophthalmoscope in the direct method: one is the direction which the rays of light take as they leave the eye under examination, and the other is for the observer to keep his own eye emmetropic; in other words, the observer *wearing his* correcting glasses should not accommodate.

Figure 162 shows that rays of light passing out of an eye divergently must be made parallel, so as to focus upon the surgeon's own retina (emmetropic), and to do this it is necessary to turn a plus lens in front of the sight-hole of the ophthalmoscope; the strength of the convex lens thus employed, other things being normal, is the amount of the refractive error of the eye being examined.

Figure 163 shows rays of light passing out of an eye convergently, and to have them parallel, so as to focus upon his own

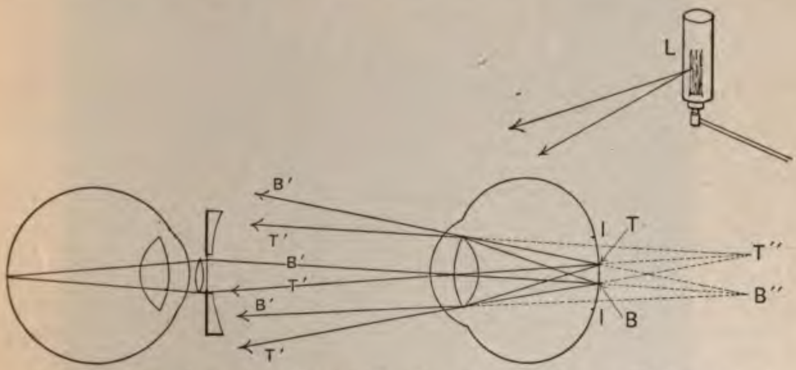


FIG. 162.—TB indicate points at the edge of the disc from which rays pass out of the eye divergently in the direction T'B', T'B', T'B', and being received by the observer's eye, are projected backward, forming an erect magnified image at T''B''. This image is not so large as that seen when looking into a myopic eye (Fig. 163).

retina (emmetropic), it is necessary to turn a concave lens in front of the sight-hole of the ophthalmoscope; the strength of the concave lens thus employed, other things being normal, is the amount of the refractive error of the eye under examination.

The Observer's Accommodation.—It has already been stated that, when using the ophthalmoscope, the observer should wear any necessary correcting lenses. If the observer has a refractive error and does not wear his glasses, he must deduct this amount from the lens used in the ophthalmoscope. If he has 2 diopters of hyperopia himself, and the lens used in the

ophthalmoscope is +4 diopters, then the eye under examination has only 2 diopters. If the observer is myopic 2 diopters and the lens in the ophthalmoscope is −4, then the eye under examination is myopic −2. It is not unusual for beginners to see the eye-ground (disc) in hyperopic eyes with a strong concave lens; this is due to the fact that they accommodate. Practice will overcome this habit, and it should be mastered as soon as possible. There are several ways of doing this: one is to begin the examination at a distance of 30 or 40 cm. from

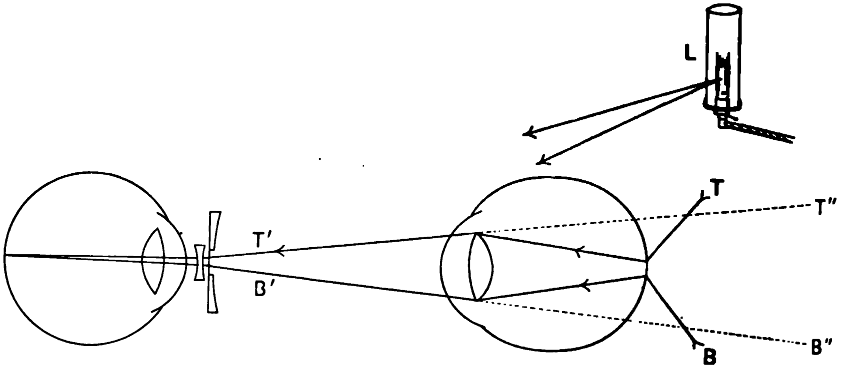


FIG. 163.—TB indicate points at the edge of the disc from which rays pass out of the eye convergently in the direction T'B', and being received by the observer's eye, are projected backward, forming an erect magnified image at T''B''. This image is much larger than that seen when looking into the hyperopic eye (Fig. 162).

the eye, with both eyes open, and to gradually approach the eye as close as 3 cm., imagining all the time that one is looking for some *remote* point; otherwise, if one begins the examination close to the eye and imagines he is going to see an object about an inch away, he will most invariably accommodate several diopters, with the result that he turns a strong concave lens in front of the sight-hole of the ophthalmoscope to neutralize his accommodation.

This explains how so many beginners diagnose all cases of hyperopia as myopia. An excellent way to learn to relax the *accommodation* is to practise reading fine print at a distance

of about 13 in. through a pair of +3 lenses placed before the surgeon's emmetropic eyes. Another good way to learn to

Fig. 164.

relax the accommodation is to practise on one of the many schematic eyes found in the shops.

Size of the Image of the Eye-ground (Figs. 162 and 163).—In concluding the subject of the direct method of examination it may be interesting to note the apparent size of the image of the eye-ground, which, it must be remembered, is virtual, erect, and enlarged; in fact, it seems to be at some distance behind the eye, and if the student has paid close attention to the study of images as formed by convex lenses, detailed in Chapter I, he need not have any difficulty in appreciating these facts.

The retina of the emmetropic eye is about 15 mm. from its nodal point; then the actual size of the emmetropic disc is $\frac{15}{250}$ of 25, or $\frac{3}{2}$, or 1.5 mm.; then 15 is to 250 as 1.5 is to 25, or 16.6—the magnification (observed) or enlargement; it is equivalent to looking at the disc through a lens of 15 mm. focus, 66 diopters.

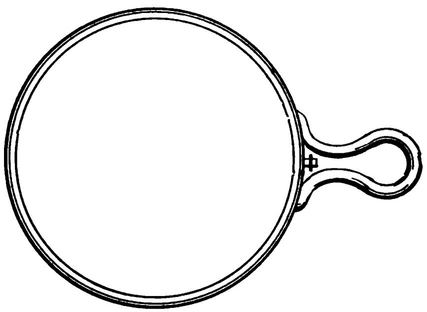


FIG. 165.

The Indirect Method (see Fig. 164).—Practising this method, the observer sees a larger part of the eye-ground at one time, but it is not so perfect in detail nor is it magnified to the same extent as in the direct method. The observer does not have to get so close to his patient, which is a decided advantage in some clinical cases. As a preliminary step, it is a decided advantage also to dilate the pupil. In addition to the ophthalmoscope, there is also required a convex lens of known strength and large aperture; the one which comes in the case with the scope is usually too small and too strong for general use. The writer prefers his +13 D. with metal rim and convenient handle, shown in Fig. 165 (reduced one-third in size).

This is held at about 3 in. in front of the eye under examina-

tion, the observer resting his little and ring fingers on the temple of the patient. The light may be over the patient's head, or to the side corresponding to the eye under examination, the patient being instructed to look with both eyes open toward the surgeon's right ear when the right eye is being examined, and toward the surgeon's left ear when the left eye is examined.

With a +4 D. in the ophthalmoscope held close to his eye, the surgeon seats himself in front of the patient at about 16 in. distant, and reflects the light through the condensing lens into the patient's eye, and then approaches or moves away from the eye until he recognizes clearly a retinal vessel or the disc; he must remember, however, that he is not looking into the eye, but is viewing an aerial image formed between the convex lens and the ophthalmoscope; this image is not only inverted but undergoes lateral inversion, so that the right side of the disc becomes the left side of the image, and *vice versa;* the upper side of the disc becomes the lower side of the image, and *vice versa. As the direct method gives an erect, virtual, and enlarged image, the indirect method produces an inverted, real, and small image. The principle of the direct method is similar to a simple microscope, and the indirect to a compound microscope.*

The size of the image depends upon the refraction of the eye and the distance of the convex lens from the eye under examination. In the standard eye this is always the same, no matter how far away from the eye the convex lens is held. To estimate the size of the image in the standard eye, all that is necessary to know is the principal focal distance of the lens employed; if a +13 D., then the image is formed at 75 mm. (3 in.), and remembering that the retina in the eye is 15 mm. back of the nodal point, the size of the image will be to the size of the disc (if that is what is looked at) as their respective distances, or as 15 is to 75, which equals 5, the magnification.

The purpose of the +4 D. in the scope is to take the place of the eye-piece in the microscope and, therefore, to magnify the image at the same time it relieves the observer's ac-

commodation. In high myopia the +4 D. may be dispensed with.

The Luminous Ophthalmoscope (Fig. 166).—This instrument is a combination of the Loring ophthalmoscope just described, with the addition of an electric light attachment. The Marple mirror is somewhat different from the mirror of the Loring instrument. It is plane, square in form and 10 mm. in diameter. The sight-hole is a vertical slit through the upper half of the mirror and the mirror is placed at an angle of 43°. Just above the handle of the instrument is a small electric lamp, and between the lamp and mirror is a strong convex lens. The rays of light from the lamp, falling upon the convex lens, are refracted very convergently, and after reflection from the mirror meet at a point about 1 in. distant. In the handle there is a small dry cell battery, and on the upper part of the handle a convenient switch which the operator uses to control the amount of current; this he does with the end of the thumb of the hand which holds the ophthalmoscope.

Fig. 166.—Luminous ophthalmoscope. One-third size.—(*De Zeng.*)

This instrument is ideal for both the direct and indirect method and has the following points of merit: The mirror and light are stationary, thus giving the observer any liberty of movement necessary without any loss of reflection from the mirror; the mirror never requires any tilting; the brilliancy or intensity of the illumination at the fundus, by virtue of the light being so close to the mirror, far exceeds that of the nonluminous instrument; for the same reason the size of the retinal illumination is made about five times larger than that by the old-style instrument. The heat from the electric lamp ($2\frac{1}{2}$ volts, $\frac{3}{4}$ ampere) is infinitesimal.

Caution.—When looking for vitreous opacities and estimating elevations and depressions the writer would caution oculists to use a weak light as the bright electric light penetrates deeply and one thus fails to see opacities unless they are very dense. and at the same time the penetrating power of the very bright electric light makes the estimate of elevations less and depressions greater than they actually are. In fact, when making estimates with the ophthalmoscope and looking for vitreous opacities the writer strongly recommends gas illumination and Loring ophthalmoscope, and not the electric ophthalmoscope.

CHAPTER VIII

EMMETROPIA—HYPEROPIA—MYOPIA

Emmetropia

Emmetropia (ἐν, "in;" μέτρον, "measure;" ὢΨ, "eye") literally means an eye in measure, or an eye which has reached that stage of development where parallel rays of light will be focused on its retina without any effort of accommodation. As the emmetropic eye is the ophthalmologist's ideal unit of measurement or goal in refraction, the beginner should know this form of eye thoroughly, so that he may recognize any departure from this standard condition. The emmetropic eye may be described in various ways, and while these descriptions may appear like repetitions, they are given for purposes of illustration.

The standard or schematic eye: Authorities differ somewhat in the exact measurements of a schematic eye, but the one suggested by Helmholtz is certainly worthy of careful consideration (see page 99).

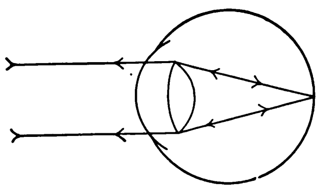


FIG. 167.

An emmetropic eye is one which, in a state of rest (without any effort of accommodation whatever), receives parallel rays of light exactly at a focus upon its fovea (see Fig. 167).

An emmetropic eye, therefore, is one which, in a state of rest, emits parallel rays of light (see Fig. 167).

An emmetropic eye is one whose fovea is situated exactly at the principal focus of its refractive system (see Fig. 167).

An emmetropic eye is one the vision of which, in a state of *rest, is adapted* for infinity.

An emmetropic eye is one which has its near point consistent with its age (see page 108).

An emmetropic eye is one which does not develop presbyopic symptoms until 45 or 50 years of age (see page 108).

An emmetropic eye, in contradistinction to a myopic eye (see page 155), is spoken of as a healthy eye, or one which shows the least amount of irritation in its choroid and retina.

Because we refer to Helmholtz's schematic eye as an emmetropic eye, it will not do to say that all eyes that measure just 23 mm. in their anteroposterior diameter are emmetropic (Fig. 168); for while an eye may be just 23 mm. in length, it may have its refractive system stronger or weaker than is consistent with its length, making it, if stronger, a myopic or long eye, and, if weaker, a short or hyperopic eye. An eye, to be emmetropic, therefore, no matter what its length, *must* have its refractive apparatus of just such strength that, in a

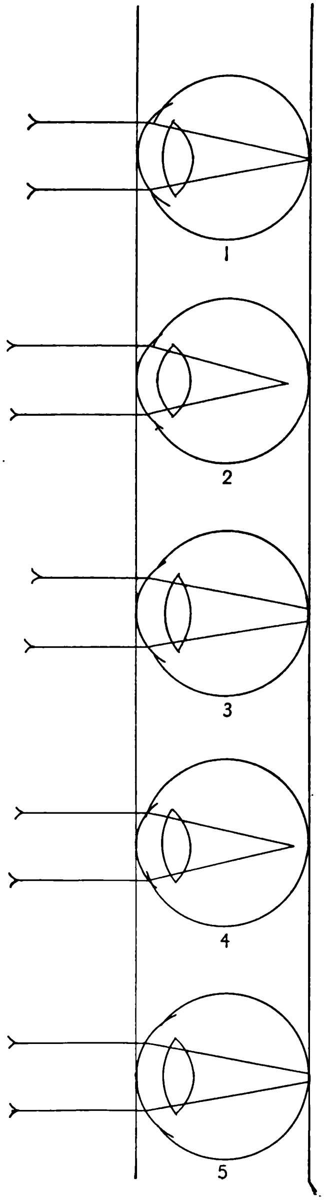


FIG. 168.—1. Emmetropia. 2. Myopia due to a strong lens. 3. Hyperopia due to a weak lens. 4. Myopia due to a short radius of curvature of cornea. 5. Hyperopia due to a long radius of curvature of cornea. The anteroposterior diameter of all these eyes is just 23 mm.

state of rest, the principal focus will coincide exactly with the cone at the fovea (Fig. 167).

Ametropia

Ametropia (ἀ, priv.; μέτρον, "a measure;" ὄψις, "sight") literally means "an eye out of measure." An ametropic eye is one which, in a state of rest, does not form a distinct image of distant objects upon its retina. An ametropic eye may be defined as one which, in a state of rest, does not focus parallel rays of light upon its fovea. An eye which is not emmetropic is ametropic. There are two forms of ametropia—axial and curvature ametropia.

Axial ametropia is the condition in which the dioptric apparatus refracts equally in all meridians, but the retina of the eye, when at rest, is either closer to, or further away from, the nodal point than the principal focus (see Figs. 169 and 171). The refraction is measured on the length of the anteroposterior axis of the eye; hence its name, axial ametropia.

Curvature ametropia, in contradistinction to axial ametropia, is the condition in which the dioptric apparatus does not refract equally in all meridians, and with the result that there is no focusing of all the rays at any one point; or curvature ametropia may be considered as that condition in which parallel rays of light entering an eye have two focal planes for two principal meridians usually at right angles to each other. Curvature ametropia is commonly spoken of as astigmatism (see Chapter IX).

Varieties of Axial Ametropia.—Axial ametropia is of two forms: one in which the eye has its fovea closer to the dioptric apparatus than its principal focus (see Fig. 169), known as the hyperopic, short, or flat eye; and the other form of eye in which the fovea is further away than its principal focus, known as the myopic or long eye (see Fig. 171).

Hyperopia or Hypermetropia

Hyperopia (ὑπέρ, "over;" ὤψ, "eye") literally means an eye which does not equal the standard condition, or an eye which is less than the standard measurement. Hyperopia is often abbreviated H. About 20 per cent. of all eyes have simple hyperopia. The hyperopic eye is spoken of as far-sighted, and the condition as one of far-sightedness. The hyperopic eye may be described in many different ways:

1. The "natural eye," or "the eye of nature."

2. The "short eye" or "flat eye." This term is used on account of its fovea lying closer to the dioptric apparatus than the principal focus.

3. Parallel rays of light passing into a hyperopic eye in a state of rest fall upon its retina or fovea before they focus (see Fig. 169).

4. Rays of light from the fovea of a hyperopic eye in a state of rest pass out divergently (see Fig. 169), and the condition is equivalent to a convex lens refracting rays of light which proceed from a point closer to the lens than its principal focus (see Fig. 85).

5. A hyperopic eye is one which, in a state of rest, can receive only convergent rays of light at a focus upon its fovea (Fig. 169); therefore, to repeat: the hyperopic eye, in a state of rest, emits divergent rays and receives convergent rays at a focus upon its fovea.

6. As convergent rays are not found in nature, and are, therefore, artificial, a hyperopic eye is one which, in a state of rest, requires a convex lens to focus parallel rays of light on its fovea (see Fig. 170).

7. A hyperopic eye is one which must accommodate for infinity, and, in fact, for all distances; in other words, a hyperopic eye in use without a correcting lens is in a *constant* state of accommodation.

8. A hyperopic eye having to use some of its accommodative

power for infinity, must, in consequence, have its near point removed beyond that of an emmetropic eye of corresponding age (see page 111).

9. From the description contained in 3, it follows that the far point of a hyperopic eye in a state of rest is negative (−), and is found by projecting the divergent rays backward to a point behind the retina (see Fig. 169).

10. From the description contained in 6, and the description of accommodation on page 109, it is natural to find the retina and choroid of many hyperopic eyes in a state of irritation.

11. From the description contained in 6 and 7, and on page 111, it follows that symptoms of presbyopia manifest themselves earlier in hyperopic than in any other form of eyes.

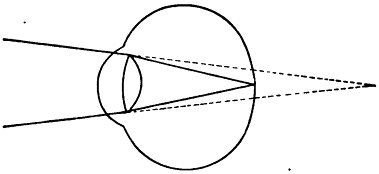


FIG. 169.

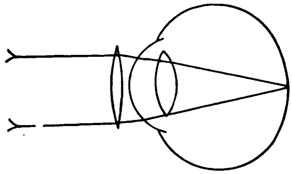


FIG. 170.

12. From the description contained in 5 (and this may appear like repetition), it follows that a hyperopic eye will accept some strength of plus glass for distant vision (see Fig. 170).

13. From 6 it is evident that the circular fibers of the ciliary muscle must become highly developed, much more so than the longitudinal fibers. Microscopically, a section of the ciliary muscle on this account will bear evidence of the character of the eye from which it came.

Causes of Hyperopia.—It is a well-known fact that the eyes of the new-born are, with comparatively few exceptions, hyperopic; such eyes are supposed to grow in their anteroposterior diameter, and at adolescence to reach that stage of development called emmetropia. It is also a well-known fact that this *ideal condition* of emmetropia is very rarely attained, the length

of the eyeball not increasing in proportion to the strength of its refractive system.

Eyes may approximate the emmetropic condition, but very seldom remain so, passing into the condition in which the fovea lies beyond the principal focus, becoming what is known as long, or myopic.

A standard eye may be made hyperopic in its refraction by removing its lens; the condition following cataract extraction (see page 370).

An eye may possibly become hyperopic in old age, from flattening of the lens due to sclerosis of its fibers, known as "hyperopia acquisita."

Any disease which will cause a flattening of the cornea in a standard eye will produce hyperopia.

A diminution in the index of refraction of the media of the standard eye will produce hyperopia.

Subdivisions of Hyperopia.—For purposes of study hyperopia has been divided into six classes or varieties:

1. **Facultative hyperopia** (abbreviated Hf.) is a condition of the eye in which the patient can overcome the error by using his accommodation. It is a condition of early life, and is voluntary. The patient can see clearly with or without a convex glass.

2. **Absolute Hyperopia** (abbreviated Ha.).—This is hyperopia that cannot be overcome by the accommodative effort. It is generally a condition of old age, and is involuntary; facultative hyperopia in youth becomes absolute in old age. Old age, in fact, may develop each variety except latent and facultative hyperopia. Absolute hyperopia exists whenever the defect is of such an amount that it cannot be overcome by the accommodation or when the accommodative power itself is gone.

3. **Relative hyperopia** (abbreviated Hr.) is where accommodation is assisted in its efforts by the internal recti muscles; in other words, the eyes squint inward (see Chapters XVI and XIX).

4. **Manifest hyperopia** (abbreviated Hm.) is represented by the strongest convex lens through which an eye can maintain distinct distant vision. Manifest hyperopia, therefore, includes facultative and absolute.

5. **Latent hyperopia** (abbreviated Hl.) is the amount of hyperopia which an eye retains when a plus lens is placed in front of it. Or latent hyperopia is the difference between the manifest hyperopia and that lens which an eye would select if its accommodation was put at rest with a cycloplegic (atropin). For example, an eye accepts a +1.25 S. as its manifest H., and, when atropin is instilled, would accept +2.75 S. for the same distant vision; then the difference between the manifest +1.25 S. and +2.75 S. (the total) is +1.50 S., which is the latent hyperopia.

6. **Total hyperopia** (abbreviated Ht.) is the full amount of the hyperopia, or is represented by the strongest glass which an eye will accept and have clear, distinct vision when in a state of rest.

Symptoms and Signs of Hyperopia.—Commonly known as eye-strain or asthenopia, these are many and various; the principal one, however, and the one that generally causes the patient to seek relief, is *headache.* Headache caused by the eyes is usually frontal, and is denominated "brow ache;" it may be frontotemporal; the pain or discomfort starting in or back of the eyes may extend to the occiput or all over the head, and be associated with all kinds of nervous manifestations. The most characteristic distinguishing feature of ocular headache is that it comes on while using the eyes, and gradually grows worse as the use of the eyes is persisted in; and, likewise, the headache gradually ceases after a few minutes' or hours' rest of the eyes. Vertex headache, or a feeling of weight on the top of the head, has been preempted by the gynecologist, and is not usually classed as ocular. The ciliary muscle being the prime factor in causing the headaches, the writer feels justified in calling it the "*headache* muscle." "Sick headaches" are largely due to eye-

strain. Various functional disorders, such as dyspepsia, constipation, biliousness, lithemia, chorea, convulsions, epileptoid diseases, hysteria, melancholia, etc., are, according to some few authorities, attributable to this condition (see Asthenopia, page 304).

Blepharitis marginalis, styes, and conjunctivitis are frequently present, and in truth the hyperopic eye on this account can often be diagnosed in public outside of the surgeon's office. A feeling as of sand in the eyes, ocular pains or postocular discomfort, a dryness of the lids, as if they would stick to the eyeballs, are common complaints, and part of the conjunctivitis. Other patients have their eyes filling with tears (epiphora) as soon as they begin reading, etc. A drowsiness or desire to sleep often comes on after or during forced accommodation.

Congestion of the choroid and retina, as evidenced by the ophthalmoscope, often go together with the blepharitis and conjunctivitis.

The patient complains that the print blurs or becomes dim after reading, and this is especially apt to occur by artificial light. When the "blur" comes on, he has to stop and rub his eyes or bathe them; and then, with additional light, he is able to continue the reading for a short time longer, when the blur again returns and the effort must be given up. Strong light stimulates the accommodation. The "hyperopic blur" is nothing more or less than a relaxation of the accommodation.

In children hyperopia sometimes simulates myopia, from the fact that the child in reading holds the print very close to the eyes and squints his lids together. He does this in order to get a larger retinal image and to relieve his accommodation; the retinal image is not clear, and the child has to read slowly; the retinal image is composed mostly of diffusion circles. The child holds the print close to his eyes to avoid using his total accommodation, which he might have to do if he held the print at a respectable distance.

He also calls into play the orbicularis palpebrarum, and nar-

rows the palpebral fissure, looking through a stenopeic slit, as it were. These cases of simulated myopia can be quickly diagnosed by:

1. The narrow palpebral fissure during the act of reading, and reading very slowly, as each letter has to be studied.

2. The fact that very few children have myopia.

3. The comparatively good distant vision, as a rule, which myopes never have, unless the myopia is of very small amount.

4. The ophthalmoscope.

The beginner in ophthalmology should be on his guard for these "pseudo-myopias," and not be guilty of putting concave lenses before hyperopic eyes.

Diagnosis of Hyperopia.—This form of ametropia may be recognized in many ways:

1. Blepharitis marginalis if present, is generally due to hyperopia.

2. Hyperopic eyes are said to be small and to have small pupils, which facts are *generally* confirmed, but myopic eyes *sometimes* appear small and have small pupils also.

3. A narrow face and short interpupillary distance are quite indicative of hyperopia, but these indexes are not infallible.

4. A child with one eye turned inward toward the nose (convergent squint) has hyperopic eyes, as a rule, the hyperopia generally not being of the same amount in the two eyes, the squinting eye *usually* being the more hyperopic.

5. It has been authoritatively stated that light-colored irises are seen in hyperopic eyes and dark irises are to be found in myopic eyes, and yet this is not always correct. German students, with their blue irises, will average from 50 per cent. to 60 per cent. of myopia.

6. Hyperopic eyes, with few exceptions, have excellent distant vision: often $\frac{VI}{VI}$, or even better. The student should be on his guard for this, and not imagine, because a patient has $\frac{VI}{VI}$ vision, that he is emmetropic; on the contrary, hyperopic

eyes accommodate for distance, and obtain this acute vision by effort.

7. The patient gives a history of accommodative asthenopia, with or without headaches coming on during or after the use of the eyes.

8. The distant vision of a hyperopic eye may remain unchanged or may be improved with the addition of a convex lens, which latter would be impossible in emmetropia and myopia.

9. The near point of a hyperopic eye without glasses lies beyond that of an emmetropic eye for a corresponding age.

10. A hyperopic eye can see fine print clearly through a convex lens at a greater distance than its principal focus, which would not be the case with any other form of eye.

Other tests for determining hyperopia are with (11) the ophthalmoscope, and (12) the retinoscope. These tests are described in the text.

Myopia

Myopia (μύειν, "to close;" ὤψ, "eye") means, literally, "to close the eye," and this origin of the name has arisen from the fact that many long eyes (myopic) squint the eyelids together when they endeavor to see beyond their far point. Myopia is abbreviated M. About 1.5 per cent. of all eyes have simple myopia. The myopic eye is spoken of as near-sighted, and the condition as one of near-sightedness. The myopic eye may be described in many different ways:

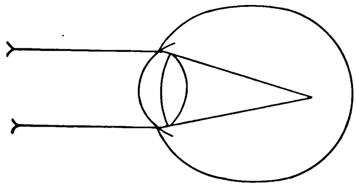


FIG. 171.

1. The long eye. The origin of this name is purely anatomic, the fovea lying beyond the principal focus of the refracting system (see Fig. 171).

2. Parallel rays of light entering a myopic eye focus in the vitreous humor before they can reach the fovea (see Fig. 171.)

3. Rays of light from the fovea of a myopic eye pass out of the eye convergently (see Figs. 140 and 172), focusing at some point inside of infinity. The refractive condition of a myopic eye is similar or equivalent to a convex lens refracting rays of light which proceed from some point farther away than its principal focus (see Fig. 83). The nearer to the eye the emergent

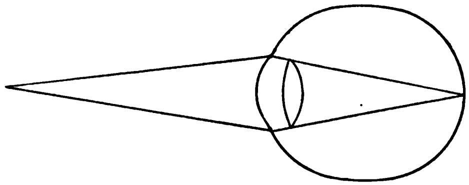


FIG. 172.

rays of light focus (in a state of repose), the longer the eye; and the farther away from the eye the emergent rays focus, the nearer the eye approaches to emmetropia, or normal length.

4. A myopic eye is one which receives rays of light which diverge from some point closer than 6 meters, at a focus on its fovea, and which emits convergent rays (see Fig. 83, and also description of conjugate foci).

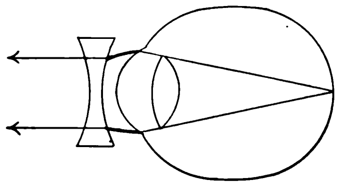


FIG. 173.

5. As parallel rays cannot focus on the fovea of a myopic eye, it is necessary to give parallel rays entering the eye a certain amount of divergence, so as to place the focus at the fovea; and to accomplish this, a concave lens must be used (see Fig. 173). A myopic eye, therefore, is one which requires a concave lens to improve distant vision (see Fig. 173).

6. A myopic eye is one whose distant vision is made worse by the addition of a convex lens.

7. A myopic eye is one which does not accommodate for distance.

8. A myopic eye having a refracting system stronger than

is consistent with its length, or *vice versa*, greater length than is consistent with its dioptric system, naturally does not use any accommodation except for points inside of its *punctum remotum*, and with the result that its amplitude of accommodation is used near by; consequently, a myopic eye is one which has a near point closer than an emmetropic eye of corresponding age (see page 111).

9. From the description contained in 3 it follows that the far point of a myopic eye is positive (+).

10. From the description contained in 3 and 7, it also follows that the myopic eye does not develop presbyopic symptoms until late in life, and if the myopia is a convenient amount (about 3 D.) presbyopic symptoms may never develop.

11. From 6 and 9 it follows that the circular fibers of the ciliary muscle are not used to the same extent in a myopic eye as in the emmetropic and especially in the hyperopic eye. Microscopically, a section of a ciliary muscle on this account will bear evidence of the character of the eye from which it came, and have the longitudinal fibers more in evidence. In some very long myopic eyes there may not be any circular fibers recognized.

12. Eyes in which the myopia is progressive are spoken of as "sick eyes," but all myopic eyes are not "sick eyes."

Causes of Myopia.—Any disease or injury which will so alter the refracting system of an eye that parallel rays must focus in front of the fovea will produce the form of eye known as long or myopic. This may be brought about in different ways: A shortening in the radius of curvature of the cornea, such as comes with conic cornea and staphyloma of the cornea; an increase in the refractive power of the lens from swelling, as often precedes cataract, and is spoken of as "false" second sight; cyclitis and iridocyclitis, which diseases cause a relaxation of the lens ligament, allowing the lens to assume a greater convexity; or ciliary spasm may produce temporarily the same condition. Diabetes and Bright's disease frequently cause a swelling of the lens and consequently a myopic refraction.

Technically, however, myopia is quite universally understood to mean a permanent elongation of the visual axis of the eye beyond the principal focus of its refracting system.

Heredity is certainly a predisposing factor in the production of myopia, but this does not mean that the babe is necessarily born with long eyes. On the contrary, the eye is very likely hyperopic at birth, and what the child may inherit is weak eye tunics. Such eyes, when placed under strain or what to them is overuse, soon become elongated. This may also be brought about or assisted by poor hygienic surroundings, poor health, or develop after an attack of typhoid or one of the eruptive fevers.

Three causes for the elongation of eyes have been brought forward by able authorities and expounded as theories, any one of which, or all three, may appear conspicuously in individual cases:

1. **Anatomically,** the size of the orbit and the broad face give a long interpupillary distance and cause excessive convergence (turning inward of the eyes) when the eyes fix at the near point.

2. **Mechanically,** when the eyes are far apart and attempt to converge, the external recti muscles press upon the outer side of the globes, flattening the eyes laterally, with the result that the point of least resistance for the compressed contents of the globes is at the posterior pole of the eye, and here it is that the pressure shows itself by an elongation of the eye backward in its anteroposterior diameter. This combination of the anatomic and mechanic theories may explain in great part the presence of myopia in the average German student or any broad-faced individual.

3. **The inflammatory** theory is that a low grade of inflammation attacks the tunics of the eye, especially at the posterior pole, and is spoken of as macular choroiditis; this is brought about by faulty use of the eyes in the school or in the home, in a *poor light* or too glaring a light improperly placed, or by using

the eyes with the head bent over the work so that the return circulation from the retina and choroid is interfered with. This inflammation or congestion of the tunics of the eye may be primary in itself or secondary to the anatomic and mechanic causes. Be this as it may, the conditions exist, and go to show more and more that myopia is actually acquired and not *per se* congenital. "The inherited congenital anomalies of refraction, particularly astigmatism, are responsible for the myopic eye, by virtue of the pathologic changes they occasion in hard-worked eyes rather than any inherited predisposition to disease" (Risley, "School Hygiene").

Symptoms and Signs of Myopia.—While the myope may complain of headache and symptoms of accommodative asthenopia, yet the principal visual complaint will be the inability to see objects distinctly which lie beyond the far point. The myope's world of clear vision is limited to the distance of the far point, where the rays of light leaving his eye come to a focus. Every object situated beyond the far point is blurred and indistinct, and the farther the object from the far point, the more indistinct it becomes. The myopic child at school soon ranks high in the class, is fond of study, of books, music, or needlework, according to the sex. The myope, in other words, is usually literary in taste. Myopes without glasses avoid out-of-door sports, such as football, baseball, golf, etc.

Diagnosis of Myopia.—This form of ametropia may be recognized in various ways:

1. The prominent eyeball. This is not a positive sign of myopia, though this and other signs are mentioned for the reason that they are often present in the myopic condition.

2. The broad face and (3) long interpupillary distance are quite significant of myopia, and yet the broadest face with longest interpupillary distance the writer ever saw was in a hyperopic subject.

4. Divergent squint usually indicates myopia, and this con-

dition is often brought about by an inability to converge, or one eye may be more myopic than its fellow, with the result that the more myopic eye turns out and soon becomes amblyopic.

5. It has been stated that myopic eyes usually have dark-colored irises, but this is often a fallacy, as is only too evident in the German student with his blue iris.

The foregoing are but signs of myopia, and are recognized by inspection; they should be looked for and carefully estimated, and each given its due consideration. Subjective and objective symptoms are the true tests of myopia, and are as follows:

6. Poor distant vision; inability to see numbers on the houses across the street or on the same side of the street; history of passing friends without speaking to them. The myope enjoys close work and takes little or no interest in sports—a history, in other words, that is in keeping with a vision of short range.

7. Good near vision; ability to see the finest print or to thread the finest needle or do the finest embroidery without glasses.

8. The near point is closer than that of an emmetropic eye of corresponding age (see page 111).

9. Distant vision is made worse by the addition of a convex lens. The writer prefers to teach the diagnosis of myopia in this way, and not to say that a concave lens will improve distant vision; of course it will, but he does not want the student to put concave lenses before the eye of the young "pseudo-myope," referred to under Hyperopia.

10. The far point is brought nearer by the addition of a convex lens. Objective methods of determining myopia are by means of the—

11. Ophthalmoscope.

12. Retinoscope.

Direct Ophthalmoscopy in Axial Ametropia.—Proficiency in this method comes only by perseverance and long practice. It should not be employed to the exclusion of other and more *exact methods*. To estimate with the ophthalmoscope which

lens is required to give an eye emmetropic vision, three very important facts should receive careful attention:

1. The distance between the surgeon's and patient's eye.
2. The surgeon's and patient's accommodation.
3. The surgeon's own refractive error.

First, the surgeon should have his eye as close to the patient's eye as possible, usually at 13 mm.; this is the anterior principal focus of the eye, and is the distance at which the patient will wear his glasses.

Second, as already explained, the observer's and patient's accommodation should be in repose. The most difficult part for the student to learn is to relax his accommodation. The ambitious student strains his accommodation (ciliary muscle) in his haste, and with the result that he thinks all eyes myopic and all eye-grounds as affected with "retinitis."

Third, the surgeon, if not emmetropic, must wear any necessary correcting lenses; otherwise, the lens in the ophthalmoscope will record his and the patient's error together, and deductions must be made accordingly. For instance, if the surgeon is hyperopic +2 S. and does not wear his glasses, and the ophthalmoscope records the fundus as seen clearly with +5 S., this would mean that the patient had +3 S. (2 of the 5 S. being the surgeon's error); or if the fundus is seen without any lens in the ophthalmoscope, then the patient's error would be −2 S. (the surgeon's +2 S. from 0 leaving −2 S.); or if the ophthalmoscope showed −2 S., then the patient's error would be −4 S.; or if the ophthalmoscope registered +2 S., then the patient would be emmetropic, and this +2 S. is the surgeon's error.

Rules.—1. When the surgeon and patient are both hyperopic or both myopic, the surgeon must subtract his correction from the lens which shows at the sight-hole in the ophthalmoscope.

2. When the surgeon's eye is hyperopic or myopic and the eye of the patient is the opposite, he must add his correction to the lens at the sight-hole in the ophthalmoscope.

With the foregoing details clearly in mind and carefully executed, the surgeon selects small vessels near the macula for his observations. If it is impossible to see these on account of the small pupil, then he will have to employ a mydriatic or be limited in his observations to the larger vessels at the disc (nerve-head, or papilla).

Whenever the vessels in the macular region are seen clearly with one and the same glass in the ophthalmoscope, the refractive error can be approximated as one of axial ametropia, and every 3 diopters, plus or minus, or any multiple of 3 diopters, represent very closely 1 mm. of lengthening or shortening of the anteroposterior diameter of the eye. For example, any eye that takes a +3 S. to make it emmetropic is just 1 mm. too short; any eye that takes a −3 S. to make it emmetropic is about 1 mm. too long. It will be observed, however, under the head of Curvature Ametropia (Astigmatism), that every 6 D. cylinder represents about 1 mm. in length, as measured on the radius of curvature of the cornea. The following table, from Nettleship, gives the exact equivalents in millimeters for axial ametropia:

H.	1 D. = 0.3 mm.	M.	1 D. = 0.3 mm.
	2 D. = 0.5 mm.		2 D. = 0.5 mm.
	3 D. = 1.0 mm.		3 D. = 0.9 mm.
	5 D. = 1.5 mm.		5 D. = 1.3 mm.
	6 D. = 2.0 mm.		6 D. = 1.75 mm.
	9 D. = 3.0 mm.		9 D. = 2.6 mm.
	12 D. = 4.0 mm.		12 D. = 3.5 mm.
			18 D. = 5.0 mm.

Indirect Method.—See page 140 for a full description of this method. Slowly withdrawing the objective lens, and the disc remaining unchanged in size, signifies emmetropia; if the disc grows uniformly smaller, it means H., and if it grows uniformly larger, it means M (see Fig. 164). This is merely a method of diagnosis, and is never used for definite measurements.

CHAPTER IX

ASTIGMATISM, OR CURVATURE AMETROPIA—TESTS FOR ASTIGMATISM

Astigmatism (from the Greek, ἀ, priv.; στίγμα, "a point").—Optically, astigmatism may be defined as the refractive condition in which rays of light from a point, passing through a lens or series of lenses, do not focus at a point.[1]

In ophthalmology astigmatism is recognized as that condition of the refractive system of an eye in which rays of light are not refracted equally in all meridians, and the resulting image of a point becomes an oval, a line, or a circle (see Fig. 174).

Or astigmatism is that condition of an eye in which there are two principal meridians, of greatest and least ametropia, each having a different focal plane.

In the standard eye the cornea is represented as a section of a sphere; anatomically, however, the cornea is generally found to be an ellipsoid of revolution, with its shortest radius of curvature (normally 7.8 mm.) in the vertical meridian.

In the study of astigmatism the meridians of minimum and maximum refraction alone are considered; they are spoken of as the principal meridians, and are usually at right angles to each other.

With very few exceptions most eyes have some astigmatism. The standard or emmetropic eye is an extremely rare condition, and plain myopic eyes (long eyes) *without* any astigmatism are

[1] In an article published by Dr. Swan M. Burnett, in "The American Journal of Ophthalmology" for December, 1903, entitled "Astigmia or Astigmatism," he draws attention to the fact that astigmatism is an erroneous word, and gives the true origin of the word from στίγμη-ης, meaning a mathematic point, whereas "στιγμα" really means a "blemish" or "brand." He therefore urges the change from astigmatism to astigmia, with the word "astigmic" as the adjective.

almost as rare as the emmetropic condition; and while plain hyperopic eyes are seen, yet statistics show that fully 80 per cent. of hyperopic eyes have astigmatism.

Astigmatism is located in the cornea or lens, or it may be a condition of both structures in one and the same eye. Astigmatism of the lens may increase or diminish the total amount of the astigmatism, or neutralize the corneal astigmatism. Astigmatism, however, is more often a condition of the cornea than of the lens.

Figure 174 shows parallel rays of light passing through an astigmatic lens in which the vertical meridian has the shortest

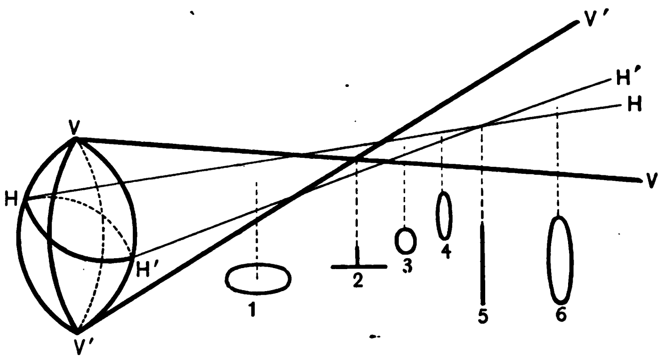


FIG. 174.

radius of curvature, with the result that those rays which pass through the vertical meridian VV' come to a focus before those in the horizontal meridian HH', which has the longest radius.

Intercepting the refracted rays at 1, 2, 3, 4, 5, and 6, the image would be at 1 a horizontal oval, at 2 a horizontal line, at 3 a circle, at 4 a vertical oval, at 5 a vertical line, and at 6 a vertical oval. The space between the points of foci of the two meridians (2 and 5) is known as Sturm's interval. The importance of this space or interval is that it represents astigmatism. Sturm's interval is the quantity which *must* be found in correcting astigmatism.

Causes of Astigmatism.—Most cases of astigmatism are congenital, and can frequently be traced to heredity. It is not uncommon for ophthalmologists of large and long experience to find astigmatism in successive generations of his patients, and frequently of corresponding axes. Acquired astigmatism may result from conic cornea, cicatrices following ulcers or wounds of the cornea, or be a temporary condition from pressure of a chalazion or other growth; and, in fact, astigmatism may develop from any disease or injury that will cause a lengthening or shortening or inequality in one or more of the meridians of the cornea or lens. Swelling of the different sectors of the lens will cause astigmatism. The visual line not passing through the center of the cornea is a cause of astigmatism, and astigmatism is the usual result following extraction of the lens. Tenotomy of one or more of the extra-ocular muscles will often change the corneal curvature.

Irregular Lenticular Astigmatism.—This is a normal condition of all clear lenses. It is often infinitesimal in amount, and on this account does not interfere with vision. It is caused by the different sectors of the lens or by the individual lens fibers themselves not being uniform in their refracting power. In this form of astigmatism a light does not appear to have a distinct edge, but, on the contrary, the edge has radiations passing from it, giving the light a stellate appearance. There is no known glass that will correct this variety of astigmatism.

Physiologic Astigmatism.—This is due to lid pressure, or temporarily to extreme pulling or contraction of the extra-ocular muscles. It is a voluntary astigmatism, and therefore not constant. It is not a condition of all eyes. The writer has demonstrated with the retinoscope and ophthalmometer that the condition can be produced in eyes not otherwise astigmatic. Drawing the lids together in the act of squinting or frowning, the patient can press the cornea from above and below, and give the horizontal meridian of the cornea a longer radius of curvature and the vertical meridian a shorter radius; or with the eye look-

ing into the telescope of the ophthalmometer, no overlapping of the mires is noted, but in some instances when told to open the eye widely and "stare" into the instrument, as much as ½ or ¾ of a diopter of astigmatism may be recorded.

This "transient" astigmatism should never be corrected with a glass (see Ophthalmometer).

Subdivisions of Astigmatism.—In addition to the astigmatisms just described, curvature ametropia has been further considered as:

1. Irregular, and
2. Regular.

1. Irregular Astigmatism.—This is usually located in the cornea, and is due primarily to some breach in the continuity of one or more of its meridians; for example, the vertical meridian may appear regular, but the horizontal meridian is not a uniform curve, is irregular at some point or points. Such meridians cannot produce clear retinal images, but, on the contrary, the resulting retinal image is hazy or irregular.

2. Regular Astigmatism.—In this variety the cornea and lens are regular in their curvatures, from the maximum to the minimum radius, and the retinal image can be made clear with correcting glasses.

Before entering upon the study of the various forms of regular astigmatism, the student's attention is called to two important facts: (*a*) That, *as a rule*, the shortest radius of curvature of the cornea is in the vertical meridian; that is to say, the vertical meridian has a stronger refracting power than the horizontal.

(*b*) The student should bear in mind that in the measurement of curvature ametropia each millimeter of lengthening or shortening of the radius of curvature is equivalent to a 6 D. cylinder. For instance, an eye which requires a +6 D. cylinder axis 90° has the horizontal radius of curvature about 1 mm. longer than the vertical radius; or an eye that requires a −6 D. cylinder axis 180° has its vertical radius of curvature about 1

mm. shorter than the horizontal. In *axial* ametropia, however, it was shown that every 3 diopter *sphere* represented about 1 mm. in length, as measured on the axis.

Varieties of Regular Astigmatism.—There are five different forms of regular astigmatism:

(*a*) Simple hyperopic. (*c*) Compound hyperopic.
(*b*) Simple myopic. (*d*) Compound myopic.
(*e*) Mixed astigmatism.

(*a*) **Simple Hyperopic Astigmatism.**—Abbreviated As. H., or H. As., or Ah. About 5½ per cent. of eyes have this form of refraction. This is a condition where one meridian of the eye is emmetropic, and the meridian at right angles to it is hyperopic (see Fig. 175); the vertical meridian focuses parallel rays on the retina, and the horizontal meridian would focus back of it. The retinal image of a point is a line, usually horizontal (see 2, in Fig. 174). The correcting lens is a plus cylinder with its axis usually at 90°, or within 45° of 90°, or it may be at any axis. Example, +2.00 cyl. axis 90°.

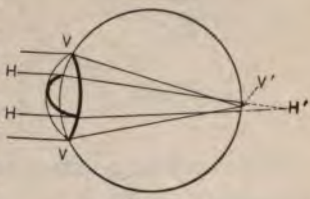


FIG. 175.

(*b*) **Simple Myopic Astigmatism.**—Abbreviated As. M., or M. As., or Am. This is not a common condition. About 1½ per cent. of all eyes have this form of astigmatism. This is a condition where one meridian of the eye is emmetropic, and the meridian at right angles to it is myopic (see Fig. 176); the horizontal meridian focuses parallel rays on the retina, and the vertical meridian focuses parallel rays in front of the retina (in the vitreous), with the result that they cross before reaching the retina. The retinal image of a point is a line, usually vertical (see Fig. 174). The correcting lens is a minus cylinder with its axis usually at 180°, or within 45° of 180°, or it may be at any axis. Example, −2.50 cyl. axis 180°.

(*c*) **Compound Hyperopic Astigmatism.**—Abbreviated H. As. Co., or Comp. Has., or H + Ah (hyperopia combined with astigmatism hyperopic). This condition represents nearly 44 per cent. of all eyes; it is the most common of all forms of refraction.

The retinal image of a point is an oval, never a line and never a circle (see 1, in Fig. 174).

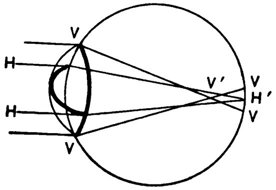


FIG. 176.

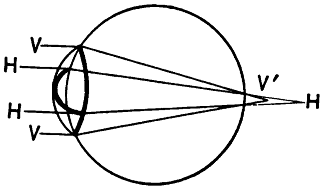


FIG. 177.

The correcting lenses are a plus sphere and a plus cylinder. Example, +2.00 S. ○ +3.00 cyl. axis 90°. Compound hyperopic astigmatism is a combination of axial ametropia (short eye) and simple hyperopic astigmatism (curvature ametropia). In this form of astigmatism both meridians have their foci back of the retina—one farther back than the other. The retina intercepts all the rays before they can focus. Figure 177 shows the condition. Usually the vertical meridian focuses nearer the retina than the horizontal.

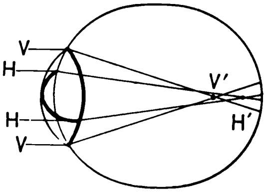


FIG. 178.

(*d*) **Compound Myopic Astigmatism.**—Abbreviated M. As. Co., or Comp. Mas., or M. + Am. (myopia combined with astigmatism myopic). This is by far the most common condition of all myopic eyes, and represents about 8 per cent. of all eyes.

The retinal image of a point is always an oval, never a line or a circle (see 6, in Fig. 174).

The correcting lenses are a minus sphere and a minus cylinder.

Example, -1 sph. ⊂ -2 cyl. axis 180°. A combination of axial ametropia (long eye) and simple myopic astigmatism.

Figure 178 shows that parallel rays have two points of foci in front of the retina—one farther front than the other.

(*e*) **Mixed Astigmatism.**—This form of refraction is found in about 6½ per cent. of all eyes, and is abbreviated in three different ways:

1. Ah + Am. (astigmatism hyperopic with astigmatism myopic).
2. H + Am. (hyperopia with astigmatism myopic).
3. M + Ah. (myopia with astigmatism hyperopic).

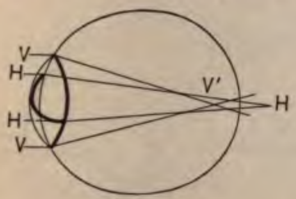


FIG. 179.

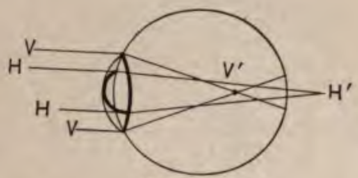


FIG. 180.

The retinal image of a point is an oval or a circle, never a line (see 3 and 4, in Fig. 174).

The correcting lenses are one of three combinations, and spoken of as crossed cylinders. Examples:

1. $+1.00$ cyl. axis 90° ⊂ -2.00 cyl. axis 180°.
2. $+1$ S. ⊂ -3 cyl. axis 180° (cylinder always stronger than the sphere).
3. -2 S. ⊂ $+3$ cyl. axis+ 90° (cylinder always stronger than the sphere).

The condition of mixed astigmatism is one of simple hyperopic astigmatism, with simple myopic astigmatism; one meridian focuses parallel rays in front of the retina and the other meridian (at right angles) focuses parallel rays back of the retina. Figures 179 and 180 show this arrangement.

Classifications of Regular Astigmatism

These subdivisions of astigmatism are merely classifications of the different forms already described, and arise from a study of the axis of shortest radius of curvature.

1. **Symmetric Astigmatism.**—When the combined values, in degrees, of the meridians of shortest or longest radii of curvature in both eyes equal 180° (no more and no less), then the astigmatism in the two eyes is spoken of as symmetric. For example, if the cylinder in the right eye is at axis 75° and in the left eye at 105°; 75° and 105° added together will make 180° (see Fig. 181). Or if each eye takes a cylinder axis at 90° they are also symmetric, 90° and 90° making 180°. If both eyes have axes 180° they are symmetric also, one meridian being considered as zero (0).

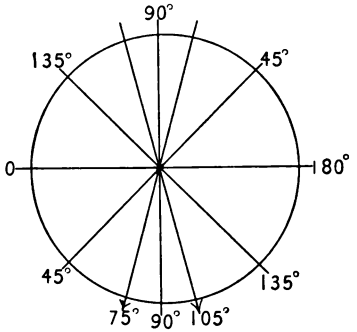


FIG. 181.—Illustrating symmetric astigmatism.

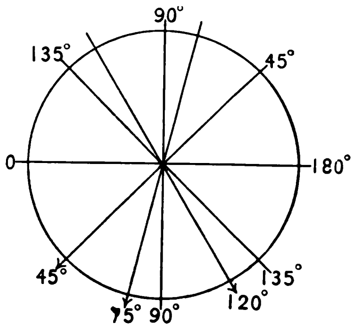


FIG. 182.—Illustrating asymmetric astigmatism.

2. **Asymmetric astigmatism** is the reverse of symmetric. and is, therefore, the condition in which the combined values, in degrees, of the cylinder axes do not make 180°. For instance, if the right eye has a cylinder at axis 75° and the left at 120°, these added together would not make 180°, but more than 180° (see Fig. 182). Or if the astigmatism in the right eye was at 35° and the left at 90°, these added together would not make 180°.

Symmetric astigmatism generally accompanies a regular physiognomy, the center of each pupil being at an equal distance from the median line of the face. Asymmetric astig-*matism usually* accompanies an asymmetric physiognomy, the

center of one pupil being farther from the median line of the face than the other.

Muscular insufficiency, hereafter to be described, is much more common and, in fact, should be looked for or anticipated in cases of asymmetric astigmatism.

3 and 4. **Astigmatism with the Rule and Astigmatism against the Rule.**—Astigmatism with the rule and astigmatism against the rule refer to the condition already described as that in which the vertical meridian of the eye, as a general rule, has the shortest radius of curvature.

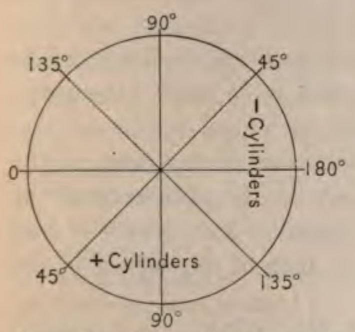


FIG. 183.—Illustrating astigmatism with the rule.

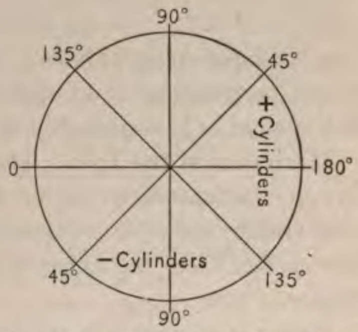


FIG. 184.—Illustrating astigmatism against the rule.

Statistic tables on astigmatism show that most eyes accept a plus cylinder at axis 90°, or within 45° (inclusive) either side of 90° (see Fig. 183); or a minus cylinder at axis 180°, or within 45° (inclusive) either side of 180°. For example, if an eye requires a plus cylinder at 45°, or at any axis from 45° up to 135° (inclusive), taking axis 90° as the median line, then the astigmatism is *with the rule*. But if an eye should require a plus cylinder within 45° either side of 180°, then the condition is one of *astigmatism against the rule* (see Fig. 184). A plus or minus cylinder at 45° or 135° is recognized as *astigmatism with the rule*.

5. **Homonymous astigmatism** is the condition in which the cylinder axis in each eye is the same.

6. Heteronymous astigmatism is the condition in which the astigmatism in one eye is with the rule and in the other eye against the rule. For example:

O. D. +2 cyl. axis 90°, and O. S. +2.00 cyl. axis 180°.

7. Homologous astigmatism is symmetric astigmatism with the rule—*i.e.*:

O. D. +1.00 cyl. axis 60°, O. S. +1.00 cyl. axis 120°.

8. Heterologous astigmatism is symmetric astigmatism against the rule—*i.e.*:

O. D. +1.00 cyl. axis 15°, O. S. +1.00 cyl. axis 165°.

9. Oblique Astigmatism.—When the axis of the astigmatism is not perpendicular or horizontal, but is at some other axis, it is spoken of as slanting or oblique.

Meridians of the Eye.—The various axes or meridians of the eye are indicated by degree markings on the periphery of the trial-frame, and by corresponding imaginary lines drawn around the eyeball from the anterior pole or apex of the cornea to the posterior pole.

Either eye (right or left) is *exactly like its fellow,* and is numbered by starting from zero (0) on the left-hand side of the horizontal meridian and counting downward to the right-hand side until this same line is again reached. This makes half a circle (hemicircle) of 180° (see Fig. 183). As the degrees in this half-circle are all carried across the eye, they maintain their individual numbering, so that axes 5, 10, 15, etc., are the same whether above or below the horizontal meridian. Hence there is no reason for having a complete circle of 360°. Some trial-frames have the upper, while others have the lower, half numbered; this makes no difference in the exact numbering; in one instance the count is made from left to right and in the other the count is made from right to left. The foreign trial-frame, as represented on page 72, may be confusing if not studied.

Symptoms of Astigmatism.—More aggravated symptoms of accommodative asthenopia are apt to be detailed by the patient, but there are, in truth, no definite symptoms whereby the presence of astigmatism can be *positively* differentiated from axial ametropia. The diagnosis of astigmatism by the physiognomy is confirmed only because most eyes are astigmatic; the simple hyperopic eye squints the eyelids together just the same as the eye that is astigmatic, so that the writer would not diagnose astigmatism by the patient's individual history of his eyes.

How to Diagnose Astigmatism.—This is one of the very early questions of the beginner in ophthalmology. Astigmatism being the prominent factor in almost all refractive work, the writer feels justified in giving this part of refraction extensive explanation. Of the various methods of diagnosing astigmatism the writer would mention the following:

1. Corneal reflex.
2. Confusion letters.
3. Placido's disc.
4. Stenopeic slit.
5. Astigmatic chart.
6. Perforated chart or disc.
7. Pray's letters.
8. The ophthalmometer.
9. Direct ophthalmoscopy.
10. Indirect ophthalmoscopy.
11. Cylindric lenses.
12. Retinoscopy.

Scheiner's test, Thomson's ametrometer, The pointed-line test and the cobalt-blue glass test as methods of diagnosing astigmatism are so seldom used and are in fact so antiquated that the writer has purposely omitted them from this volume.

1. The Corneal Reflex Test.—The cornea and underlying aqueous representing a spheric mirror, naturally furnish a small image of surrounding objects. If the cornea is astigmatic, the catoptric image must be correspondingly distorted. To make the examination, the patient stands facing a window, and the surgeon at one side observes the image of the window-panes in the corneal mirror; these will be broadened or lengthened, or they may appear inclined, according to the axis and character of the astigmatism. This test is not commonly used, is often overlooked; in fact, unless the astigmatism is of considerable degree, it is not a valuable test.

2. Confusion Letters.—Letters on the card which is used for testing distant vision are arranged in such order that those which have a resemblance are placed next to each other (Figs. 294 and 295). For example, X and K, Z and E, O and D, C and G, P and F, S and B, V and Y, H and N, A and R, etc. The patient, in deciphering these letters in the line corresponding to his best vision, often miscalls them, and cannot tell an X from a K, or a Z from an E, etc. These letters are, therefore, spoken of as confusion letters. This is a very good general test, but is not infallible, as a patient with opacities in the media will make similar mistakes.

FIG. 185.

3. Placido's Disc or Keratometer (see Fig. 185).—To a wooden handle is secured a round piece of thin sheet-iron 8 in. in diameter, and at its center is a small, round 5 mm. opening. On one side the disc is painted in alternate concentric circles or bands in black and white; these circles are not equidistant, the radii of the several circles being calculated according to the law of tangents, so that when reflected on a cornea of spheric curvature they appear equidistant in the image. On the reverse side is placed a slot to hold a convex lens for magnifying purposes. To use this disc, the patient is placed with his back to a strong light from a window, or an artificial light may be placed over his head. The surgeon holds the disc with the

sight-hole close in front of his own eye, and with the light illuminating the disc, the patient is instructed to look into the perforation. The surgeon then approaches the eye until the corneal image of the outer edge of the instrument corresponds to the outer edge of the patient's cornea. When this distance is reached, a convex 2, 3, or 4 D. sphere may be placed in the slot of the disc so as to magnify the corneal image. If the cornea is not astigmatic, then the black and white circles will appear uniform throughout; but if there is astigmatism, the circles will appear more or less oval. If irregular astigmatism or conic cornea is present, the circles will appear broken or distorted in certain parts. This test has become almost obsolete.

FIG. 186.

4. Stenopeic Slit (see Fig. 186).—This is a round metal disc of the size of the trial-lens, and contains a central slit or opening about 25 mm. long and 1 or 2 mm. wide. The stenopeic slits sold in the shops have various breadths of openings, from ½ to 2 mm.; that with the 1 mm. opening is the one recommended. The purpose of the slit is to cut off or exclude all rays of light at right angles to its position in front of the eye. When placed at axis 90, all rays in the horizontal meridian are excluded; when placed at axis 180, all rays in the vertical meridian are cut off, etc. To use the stenopeic slit, place it in the trial-frame in front of the eye to be examined, the fellow eye being covered. The patient is instructed to read the letters on the distant test-card, and as he does so, the slit is slowly turned through the different meridians. If the vision remains the same, no matter through which meridian the patient reads, astigmatism may be absent; but if the patient selects one me-

ridian in which he sees better, and another meridian at right angles in which he does not see so well, astigmatism is usually present. For instance, if the slit is at axis 75° and the patient

FIG. 187.—Astigmatic charts of Dr. John Green.

reads $\frac{\text{VI}}{\text{XII}}$, at axis 165 he reads $\frac{\text{VI}}{\text{LX}}$, then he is astigmatic and in the 165 meridian. The amount of the astigmatism can be calculated by placing spheric lenses back of the slit and finding *the difference* in strength of the spheres which bring the vision

up to the normal. For example, when the slit is at axis 75 and the patient reads $\frac{VI}{XII}$, if a +1.50 S. is used, and the vision becomes $\frac{VI}{VI}$, then 1.50 corrects axis 75. Turning the slit to axis 165, and proceeding in the same way, if +2.25 S. brings the vision from $\frac{VI}{LX}$ to $\frac{VI}{VI}$, then +2.25 corrects axis 165, the difference between the +1.50 and +2.25 being 0.75 D., and the formula would be +1.50 sph. $\bigcirc$ +0.75 cyl. axis 75°. This test is not often used, and when resorted to, the eyes, if

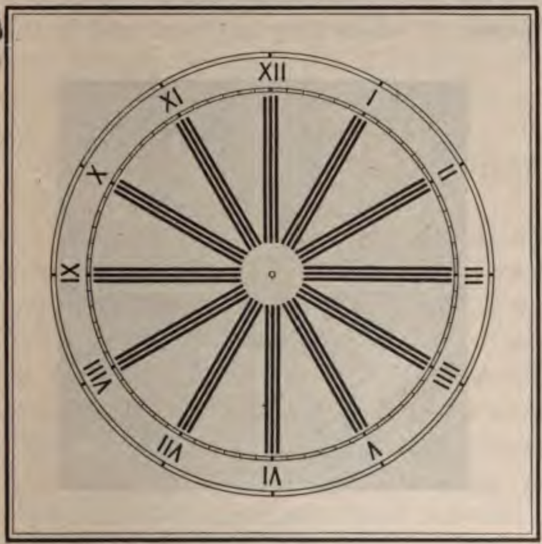


FIG. 188.

less than 45 years of age, should be under the influence of a cycloplegic. This test is of special service in some cases of mixed astigmatism, irregular astigmatism, presbyopia, and aphakia.

5. Astigmatic Chart.—There is an infinite variety of these cards (see Figs. 187 and 296), and the student is puzzled which one to select. Ordinarily, the "clock-dial" will answer every purpose (Fig. 188). This is a white card[1] with peripheral

[1] A black card with white lines is also used (see Fig. 189).

Roman characters corresponding to the characters on the clock-face, hence its name. From these figures a series of three parallel and uniformly black lines, with interspaces of the same width as the lines, cross from XII to VI, III to IX, IIII to X, V to XI, VII to I, and VIII to II. This chart should be so calculated that the lines and interspaces will form an angle of 5′ in width consistent with the distance at which the test is to be made; if at 6 meters, 8.7 mm.; if at 4 meters, 5.8 mm. In most charts the lines subtend an angle much greater than 5′ for the distance at which they are used, and in this way the

FIG. 189.

true delicacy of the test for small errors or amounts of astigmatism is sacrificed. The purpose of the chart is to detect, by the patient's answer, whether astigmatism is present, and, if so, in which meridian.

The chart, uniformly illuminated by reflection from a steady artificial light, is placed on a horizontal line perpendicular to the patient's eyes; it should never be hung at an angle, and must always be perfectly flat. Each eye is to be tested separately. Looking at such a chart, if all the lines appear equally black, *astigmatism* of any considerable degree or amount may often

be excluded; but if the patient selects one series of lines as darker than others, then the presence of astigmatism may be diagnosed. If the astigmatism is of a very high degree, the patient may see the three lines as one solid black line without interspaces.

RULE 1.—The meridian of the eye which corresponds to the dark lines selected is the meridian of astigmatism.

Example.—If the horizontal lines (from III to IX) appear darker than all the others, then it is the horizontal meridian (0 or 180°) of the eye which is astigmatic. Or if the lines from VI to XII are darkest, then the vertical meridian of the eye is astigmatic. In other words, the series of darkest lines indicates the meridian of greatest ametropia.

RULE 2.—The axis of the cylinder in the prescription will be opposite to the meridian of the dark lines.

Example.—A patient who requires a plus cylinder at axis 90° sees the horizontal lines (from III to IX) as very dark, and the lines from VI to XII not so dark, and the axis of the cylinder in the prescription will be opposite to 180°, *i.e.*, at 90°.

According to the definition of "astigmatism with the rule" and "astigmatism against the rule," it follows that, with few exceptions, those patients who select a series of lines at 180°, or within 45° either side of 180°, as darker than other lines, have hyperopic astigmatism, whereas those who select a series of lines at 90°, or within 45° either side of 90°, have myopic astigmatism.

According to the definition of symmetric astigmatism, a patient's right eye selecting the lines at 90° or 180° as darker than those at right angles, will select the same series of dark lines in the left eye. If the series of dark lines with the right eye is from II to VIII, then the left eye selects the dark lines from X to IV, etc.

The clock-dial is the form of chart in common use, and as a test for astigmatism is not without considerable merit.

When the astigmatism is of small amount, it may not be

recognized by means of the clock-dial until after the spheric correction has been placed before the eye or after a cycloplegic has been instilled.

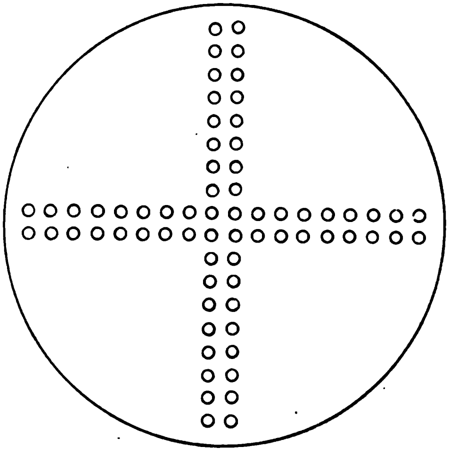


FIG. 190.

6. The Perforated Disc (Fig. 190).—This is a modification of the astigmatic chart. A piece of white cardboard or metal, about 10 in. square, has small, round perforations made in it of certain definite size. Each perforation is separated from its neighbor by the distance of its diameter. These openings are arranged in series of one, two, or three parallel lines. This chart or disc is hung on the window-pane, or an illumination is placed behind it. The patient, looking at the disc, signifies which series of perforations appear to coalesce and form lines. This test is not commonly known or used. It might be a valuable test if there was any convenient way of illuminating it from behind (Page 238).

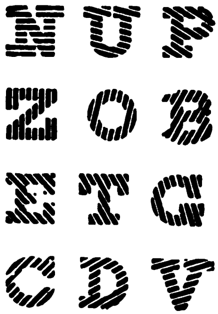


FIG. 191.

7. Pray's Letters (Fig. 191).—These letters are of the Old *English type,* and composed of strokes which run in different

meridians. The patient, looking at these letters, selects that letter which appears darker than all the rest. The direction of the lines in the letter selected corresponds to the meridian of greatest ametropia. This test is very confusing to the patient, who sees first one letter and then another as darker than its fellows. This test is not in common use and like Placido's disc is obsolete.

FIG. 192.

8. The Ophthalmometer (see Figs. 192, 193, and 194).—This name literally means an "eye measure," but as the instrument measures only the different radii of corneal curvature, a much better name would be keratometer, or measure of the corneal radii. The object of the ophthalmometer is the measurement of corneal curves by means of catoptric images viewed through a telescope.

The ophthalmometer consists of a telescope which contains

a Wollaston birefrangent prism placed between two biconvex lenses. Attached to the telescope is a graduated arc, upon which are placed two white enameled objects (Fig. 193) called mires (targets). (See Figs. 193, 195, and 196.) The left mire is stationary, and is made up of two 3 cm. squares, separated by a black line 2 mm. wide; the right mire is movable and

FIG. 193.

graduated into steps, each 5 mm. wide; a black line passes through the middle of these steps. The mires on the ophthalmometer pictured in Fig. 194 are themselves illuminated by small electric lights inserted from above. This instrument is much more modern than the one pictured in Fig. 193. For purposes of focusing, the telescope is mounted on a movable *tripod*. The patient is seated with his chin and forehead resting

in a frame. At the side of the frame, and attached to it, are two or four electric lights or two Argand burners, which illuminate the mires. The surgeon, looking through the eye-piece of the telescope, focuses the center of the patient's cornea until he sees two images of each mire clearly; then he selects the two central images for further study and ignores the peripheral

FIG. 194.—The universal ophthalmometer.

images. The next step is to move the right-hand mire until these two images of the mires occupy the center or pole of the cornea, so that their inner edges just touch and the black line in each makes one continuous black line through both (see Fig. 196); and to do the latter, the barrel of the telescope may have to be gradually revolved from left to right or right to left, but never more than 45° either way. When this position is ob-

tained, the axis or meridian is noted by the arrow, which points to the figure on the dial at the back of the arc, or, as in some old instruments, on the front of the dial. This position of the mires is spoken of as the primary position.

Revolving the telescope to the opposite meridian (meridian at right angles), which is called the secondary position, the observer notes any change which may have taken place in the relative positions of the mires. If they have not changed, but still maintain their edges in apposition, as in the primary position, then the cornea has a uniform curvature throughout, and there is no astigmatism of the cornea present. If, however, when the secondary position is reached and the catoptric image of the mires with the steps has encroached upon the catoptric image of the stationary mire, then the astigmatism is calculated by the amount of this overlapping (see Fig. 166).

FIG. 195.

FIG. 196.

Each step representing 1 diopter of astigmatism, one-half a step of overlapping would represent ½ a diopter, etc. If, in making the change from the primary to the secondary position, the mires should separate, then the surgeon would know that his secondary position should have been his primary position, and he will have to make a corresponding change.

As already stated, lenticular astigmatism is not a condition to be ignored, as only too often it will add to, diminish or even neutralize corneal astigmatism, so that in point of fact the ophthalmometric findings are more often useless than of real value in estimating the *total* refractive error. Cylinders should never be prescribed from the ophthalmometric findings until carefully confirmed by other and much more reliable tests (see Physiologic Astigmatism, page 163). As a keratometer, the instrument cannot be excelled, and, therefore, it has a place in testing the refraction in cases of aphakia. The ophthalmometer as a means of diagnosis is suggestive rather than positive.

9. Estimation of Curvature Ametropia (Astigmatism) with the Ophthalmoscope, Direct Method.—The presence of astigmatism is diagnosed by the direct method from the fact that the vessels or details of the fundus are not all seen clearly with one and the same glass in the ophthalmoscope; in other words, the vessels passing up and down on a disc may be seen clearly with a different lens in the ophthalmoscope than is required to see the vessels passing laterally or at right angles. The amount of the astigmatism is the difference in the strength of the respective lenses used for this purpose; for instance, if the vertical vessels are seen best with a +4 S., and the horizontal vessels with a +2 S., then the amount of the astigmatism would be +2 D.

When using the ophthalmoscope for making refractive estimates in astigmatic eyes, the student should remember that the glass with which a vessel is seen distinctly in one meridian represents the amount of the refraction in the meridian at right angles to this vessel. In other words, each vessel in the eye-ground of an astigmatic eye is seen clearest through the meridian at right angles to its course. This is a puzzle to the beginner, but he must remember that cylinders refract opposite to their axes. In estimating the refractions with the ophthalmoscope, the observer looks first at the shape of the disc; if it appears oval, this would be an evidence of astigmatism; secondly, if the upper and lower edges of the disc are seen clearly with a different strength glass than that required to see the inner and outer margins, then this would be a further evidence of the presence of astigmatism; but the third and confirmatory test of the presence of astigmatism should be the different strength glasses required to see the vessels distinctly in the neighborhood of the macula. An eye having an oval nerve, whose edges can all be seen clearly with one and the same glass in the ophthalmoscope is not usually astigmatic.

Examples of estimated refraction by the direct method:

Simple Hyperopic Astigmatism.—Vertical vessels seen with a +1 S. and horizontal vessels seen without any lens would equal +1.00 cyl. axis 90°.

Simple Myopic Astigmatism.—Vertical vessels seen without any lens and horizontal vessels seen with −3 S. would equal −3 cyl. axis 180°.

Compound Hyperopic Astigmatism.—Vertical vessels seen with +4 S. and horizontal vessels seen with +3 S. would equal +3.00 S. ⊂⊃ +1.00 cyl. axis 90°.

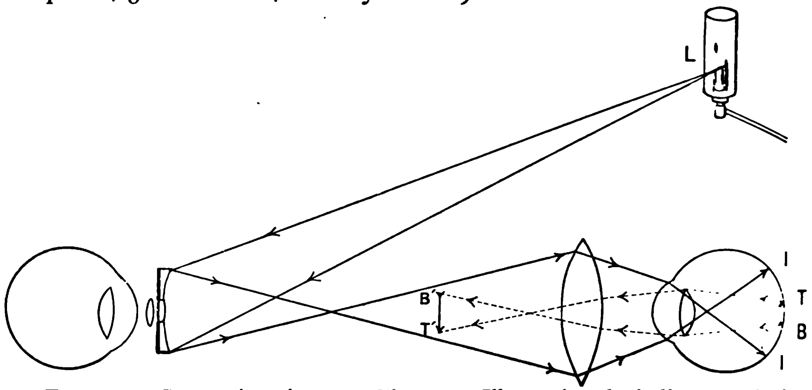


FIG. 197.—Companion picture to Fig. 163. **Illustrating the indirect method. Rays from the lamp (L) are reflected convergently from the mirror of the ophthalmoscope, and, passing through the convex lens and into the eye, produce a large retinal illumination, extending from I to I. TB are rays from the edge of the disc, and, leaving the eye parallel, pass through the convex lens and from an inverted aerial image of the disc at T'B'. The +4 S. in the ophthalmoscope magnifies the image T'B'.**

Compound Myopic Astigmatism.—Vertical vessels seen with −2 S. and horizontal vessels seen with −5 S. would equal −2.00 S. ⊂⊃ −3.00 cyl. axis 180°.

Mixed Astigmatism.—Vertical vessels seen with +2 S. and horizontal vessels seen with −3 S. would equal −3.00 S. ⊂⊃ +5.00 cyl. axis 90°.

10. Diagnosis of the Character of the Refraction by the Indirect Method (see Fig. 163 and page 140).—There is nothing exact about this method, and the refractive error, to be recognized, must be considerable.

1. Gradually withdrawing the lens (objective) from in front of the eye, if the aerial image of the disc retains its uniform size in one meridian, it signifies emmetropia for that meridian; but if it grows smaller in one meridian, that meridian is hyperopic; or if larger, then that meridian is myopic.

2. If the image grows smaller, but more so in one meridian than the other, it signifies compound hyperopia. If the image grows larger, but more so in one meridian than the other, then the condition is one of compound myopia. The image growing smaller in one meridian, while in the other it grows larger, indicates mixed astigmatism.

11. **The cylinder lens test** for astigmatism is described under Applied Refraction, and page 313.

12. **Retinoscopy** is described in Chapter X.

CHAPTER X

RETINOSCOPY.—DEFINITION.—NAMES.—PRINCIPLE AND VALUE OF RETINOSCOPY.—SUGGESTIONS TO THE BEGINNER

Definition.—Retinoscopy may be defined as the method of estimating the refraction of an eye by reflecting into it rays of light from a plane or concave mirror, and observing the movement which the retinal illumination makes when tilting the mirror and reflecting the light through the different meridians.

Names.—Shadow test, dioptroscopy, fundus-reflex test, keratoscopy, fantoscopy, pupilloscopy, retinophotoscopy, retinoskiascopy, skiascopy, umbrascopy, koroscopy, etc., are some of the other names given to this method of estimating the refraction, and their number and greater or less inappropriateness have had much to do, no doubt, with keeping retinoscopy in the background of ophthalmology instead of giving it the prominence which it more justly deserved and is now receiving from ophthalmologists in all parts of the world.

The principle of retinoscopy is the finding of the point of reversal (the far-point of a myopic eye), and to do this, if an eye is not already sufficiently myopic, it will be necessary to place in front of it such a lens, or series of lenses, as will bring the emergent rays of light to a focus at a certain definite distance, usually at 1 meter (see Point of Reversal, Chapter XIII).

Value of Retinoscopy.—Those who would criticize retinoscopy because "we see nothing and think nothing of the condition of the fundus," base their criticism apparently on the name retinoscopy, rather than from any great amount of practical experience with the method. While admitting that the ophthalmoscope in front of a well-trained eye will often give a close estimate of the refractive error of the eye under examination, yet only to the few does such skill obtain, and even *then there* is that uncertainty which does not attach itself

to the retinoscope in competent hands. The ophthalmologist who knows how to use the retinoscopic mirror accurately has the advantage of his confrères who are ignorant of the test; it gives him a position decidedly independent of his patient, and puts him above the common level of those who are tied to the trial-lenses and the patient's uncertain answers. Furthermore, when it is remembered that from 50 to 80 per cent. of the patients consulting the ophthalmologist do so for an error of refraction, it is well that he be most capable in this important branch of the subject.

The wonderful advantage of retinoscopy over other methods needs no argument to uphold it; the rapidly increasing number of retinoscopists testify to its merits.

The writer, from his constant use of the mirror, would suggest the following axiom: That, *with an eye otherwise normal except for its refractive error, and being under the influence of a reliable cycloplegic, there is no more accurate objective method of obtaining its exact correction than by retinoscopy.*

Retinoscopy gives the following advantages:

The character of the refraction is quickly diagnosed.

The exact refraction is obtained without questioning the patient.

Little time is required to make the test.

No expensive apparatus is necessarily required.

Its great value can never be overestimated in cases of nystagmus, young children, amblyopia, aphakia, illiterates, and the feeble-minded.

From what has just been stated, it must not be understood that the patient's glasses are ordered immediately from the findings obtained by retinoscopy; for, on the contrary, all retinoscopic work, like ophthalmometry in general, should, when possible, be confirmed at the trial-case.

It is only in the feeble-minded, in young children, and in cases of amblyopia that glasses are ordered direct from the findings obtained in the dark room.

The subjective method of placing lenses before the patient's eyes and letting him decide by asking "is this better?" or "is this worse?" only too often fatigues the examiner and worries the patient, giving him or her a dread or fear of inaccuracy that does not satisfy the surgeon or tend to inspire the patient. Whereas, when the neutralizing lenses found by retinoscopy are placed before the patient's eyes and he obtains a visual acuity of $\frac{6}{6}$ or $\frac{20}{20}$ or more, it is easy, if there is any doubt, to hold up a plus and a minus quarter diopter glass respectively in front of this correction, and let the patient tell at once if either glass improves or diminishes the vision.

The writer is not condemning the subjective or other methods of estimating the refraction, nor is he trying to extol too highly the shadow test, yet he would remind those who try retinoscopy, fail, and then ridicule it, that the fault with them is *back* and not in front of the mirror.

Suggestions to the Beginner.—To obtain proficiency in retinoscopy there is much to be understood. Careful attention to details *must* be given, and not a little patience possessed, as it is not a method that is acquired in a day, and it is only after weeks of constant application that accuracy is acquired. Therefore the beginner is strongly advised to learn the major points from one of the many schematic eyes in the market before attempting the human eye. At the same time he should be perfectly familiar with the action of the different cycloplegics and the laws of refraction and dioptrics, as an understanding of conjugate foci is really the underlying principle of the method—*i.e.*, a point on the retina being one focus and the myopic or artificially made far-point the other focus.

What is meant by major points applies more particularly to the study of the retinal illumination, its direction and apparent rate of movement when the mirror is tilted, also the form or shape of the illumination, the distance between the observer and the patient, how to handle the mirror, etc., all of which are referred to under their special headings.

CHAPTER XI

RETINOSCOPE.—LIGHT.—LIGHT-SCREEN BRACKET.—DARK ROOM.—SOURCE OF LIGHT AND POSITION OF MIRROR.—OBSERVER AND PATIENT.—LUMINOUS RETINOSCOPE

The Retinoscope, or Mirror.—Two forms of the plane mirror are in use—the one large, 4 cm. in diameter with a 4- or 5-mm. sight-hole often cut through the glass; and the other small, 2 cm. in diameter, on a 4-cm. metal disc, with sight-hole 2 mm. in diameter, *not* cut through the glass, the quicksilver or plating alone being removed. By thus leaving the glass at the sight-hole, additional reflecting surface is obtained at this point, which assists materially in exact work, as it diminishes the dark central shadow that shows so conspicuously at times, and particularly when the sight-hole is cut through the glass. The small mirror has an advantage over the large by reducing the area of reflected light, as only a 1-cm. area on each side of the sight-hole is of particular use. The small plane mirror is the one recommended, and is made with either a straight or folding handle (see Figs. 198–210); the latter is for the purpose of protecting the mirror when carried in the pocket. The purpose of the metal disc on which the small mirror is secured is to keep the light out of the observer's eye, and enable him to rest the instrument against the brow and side of the nose; but if its size should appear small, the observer can easily have a larger one made to suit his convenience. The white letters H. C. E. on the metal disc are for the patient to look at while the eye is being examined and the lenses changed before his eye. The plating or silvering on the mirror should be of the best, and free from any flaws or imperfections, for on its quality depends,

in part, the good reflecting power of the mirror, which is very important.

FIG. 198.

The central shadow just referred to as the result of the sight-hole had best be seen by the beginner by reflecting the light from the mirror onto a white surface, before he begins any study, as this dark area may annoy him later if he does not understand its origin.

The Light.—This should be steady, clear, and white. The Welsbach possesses all these qualities, but unfortunately its delicate mantle will not stand much jarring, and, as a consequence, is easily broken, causing much loss of time and annoyance. The electric light made with a twisted carbon and ground-glass covering having a round center of clear glass is becoming quite popular. For constant service, however, the Argand burner is decidedly the best, when the asbestos light-screen is used to intercept the heat. Whatever light is employed, it is well to have it on an extension bracket, so that the observer may raise or lower it or move it toward or away from the patient, as necessary (see Fig. 199).

When gas or electric light is not at hand, a student's oil-lamp, with a suitable light-screen, will answer every purpose (see Fig. 200).

The light-screen, or cover chimney, is made of 1/8-in. asbestos, and of sufficient size (6 cm. in diameter by 21 in height) to fit over the glass chimney of the Argand burner (see Figs. 201 and 202).

Attached to the screen are two superimposed revolving discs that furnish four round openings, respectively 5, 10, 20, and 30 mm., any one of which may be turned into place as occasion may require. Care should be taken that the opening used is placed

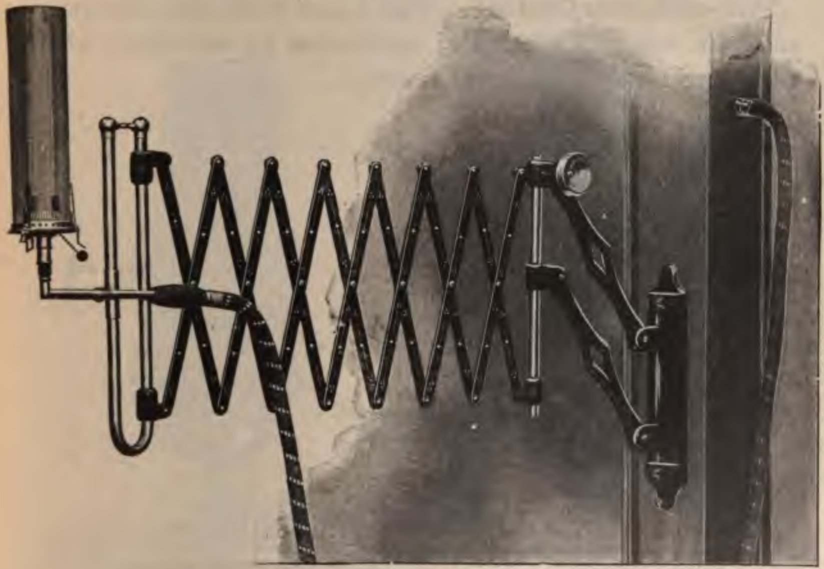


Fig. 199.

opposite to the brightest, and never opposite to the edge of the blue part of the flame. Formerly these screens were made of sheet-iron, but the asbestos has been found preferable, as it does not radiate the heat to the same extent as the iron. The purpose of the light-screen is to cover all of the flame except the portion which presents at the opening in the disc. Figure 203 shows the author's new light-screen, which was described on page 1378 in the "Journal of the American Medical Associa-

tion," December 3, 1898. This is a more convenient screen for retinoscopy than the one shown in Fig. 201. It is made by attaching an iris diaphragm to an asbestos chimney. The amount of light passing through the diaphragm is easily controlled by an ivory-tipped lever at the left-hand side; and an index on the periphery records the diameter of the opening in use, from 1 to 30 mm.

Ten-millimeter Opening.—This will be used in almost all retinoscopic work by the beginner.

Five-millimeter Opening.—This is used to the best advantage and with no small amount of satisfaction by the expert when working close to the point of reversal.

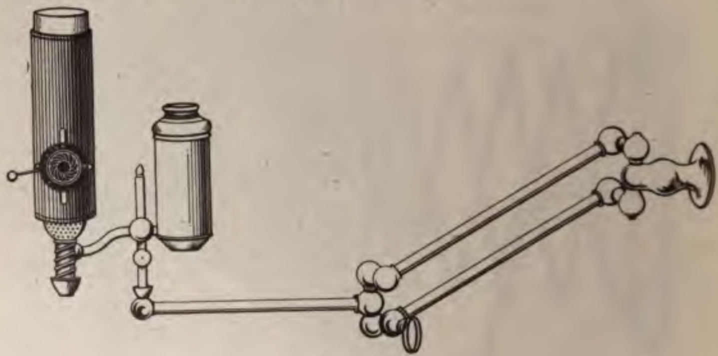


FIG. 200.

The room must be darkened—and the darker the better; all other sources of light except the one in use should be excluded. It must not be supposed from this that the room must have its walls and ceiling blackened; on the contrary, if the shades are drawn, the room will be sufficiently dark, though of course a room with walls painted black or draped in black felt would be best, as giving a greater contrast to the condition to be studied. The exclusion of other lights, or beams of light, must be insisted upon, as the principal use of the darkened room is to keep all light except the light in use out of the eye to be examined, and *also not to* have other lights reflected from the mirror.

As the method of using the concave mirror with source of light (20- or 30-mm. opening in screen) beyond its principal focus (usually over and beyond the patient's head) has been superseded by the simpler and easier method of using the small plane mirror with source of light (½- or 1-cm. opening in light-screen) brought as close to the mirror as possible, the description of retinoscopy which follows will refer to the latter.

The Source of Light and Position of the Mirror.—The rays of light coming out of the round opening in the light-screen

FIG. 201.—The author's light-screen, or cover chimney.
(For a further description, see Chapter XV.)

FIG. 202.—The author's new light-screen.

should be 5 or 6 in. to the left and front of the observer, so that they may pass *in front* of the left eye and fall upon the mirror held before the right, thus leaving the observer's left eye in comparative darkness; or the observer may use the mirror before the left eye in case he is left-handed and has the light to his right. It is always best for the observer to keep both eyes wide open and to avoid having any light fall into the unused eye, which would cause him much annoyance. Some observers

hold the mirror before the eye next to the screen, but this is not recommended, for the reasons just mentioned.

The observer need not make any note of his accommodation, as in using the ophthalmoscope, but, as he requires very acute vision, he should wear any necessary correcting glasses. *Any observer whose vision does not approximate 6/6 in the eye which he uses will not get much satisfaction from retinoscopy.*

FIG. 203.—The De Zeng ideal electric retinoscope.

He should take his seat facing the patient, and, as the strength or brilliancy of the reflected light rapidly weakens as the distance between the mirror and the light-screen is increased, he should have the light-screen close to his face (not farther away than 6 in.) if he wishes to get the fullest possible strength of light on the mirror.

As the light appears just as far back in the mirror as it is in front of it, then the nearer these two objects are brought together, the more nearly do they become as one. When working close to the point of reversal, more exact work will be accomplished if this distance between the light and mirror is very short. The nearer together the light and mirror, the brighter the retinal illumination, and greater contrast, or sharper cut edge between illumination and surrounding shadow. The further the light from the mirror, the dimmer the retinal illumination, and there will appear, under certain conditions, a very conspicuous central shadow as the result of the sight-hole in the mirror—*two very serious objections.*

The DeZeng Ideal Electric Retinoscope (Fig. 204).—This instrument does away with electric wires, therefore giving it portability. The handle is made of aluminum and designed to hold a two-cell battery of regular stock size. This handle is convenient to hold and has a compressible circuit breaker con-

veniently located for the thumb of the operator. It is arranged for either a touch or a fixing contact, the lamp being lighted either by pressing the extending arm against the handle or swinging it around in contact with the clip on the top of the cap as desired.

The mirror is the author's small plane mirror with sight-hole made by removing the silvering only. The fixation letters on the disc are those suggested and described by the author. These letters are quite cleverly illuminated by the light from the lamp passing through an opening in the tube. Tiny tungsten lamps are supplied for this retinoscope.

The patient *must have his accommodation thoroughly relaxed with a reliable cycloplegic,* and should be seated comfortably, 1 meter distant, in front of the observer, with his vision steadily fixed on the observer's forehead, just above the mirror. Or, what is even better, the patient may concentrate his vision on the letters at the edge of the metal disc of the mirror (Figs. 198, 203) or on the observer's forehead, but never directly into the mirror, as that would soon irritate and compel him to close his eye.

In this way the patient avoids the strain of looking into the bright reflected light, and at the same time the *macular region* is refracted (see Fig. 224). It is customary to cover the patient's *other* eye while its fellow is being refracted; for obvious reasons this is specially important in cases of "squint." The axonometer placed before the eye being examined is a decided advantage in any instance (see page 228 and Fig. 235).

CHAPTER XII

DISTANCE OF SURGEON FROM PATIENT.—ARRANGEMENT OF PATIENT, LIGHT, AND OBSERVER.—REFLECTION FROM MIRROR.—HOW TO USE THE MIRROR.—WHAT THE OBSERVER SEES.—RETINAL ILLUMINATION.—SHADOW.—WHERE TO LOOK AND WHAT TO LOOK FOR

Distance of Surgeon from Patient.—There is no fixed rule for this, and each surgeon may select his own distance. It might be well for the beginner to try different distances and then choose for himself. The writer prefers a 1-meter distance, and with few exceptions adheres to it. Some prefer 6 meters, others 2 meters, etc. The distance of 1 meter has important advantages: There is no necessity for getting up to place lenses in front of the patient's eye, as the patient or surgeon, or both, may lean forward for this purpose, if necessary. Another advantage is that at 1-meter distance there is a uniform allowance of 1 diopter in the estimate, which will be explained more fully under Rules for Retinoscopy at One Meter. To get the patient's eye and the observer's forehead just 1 meter apart, the distance may be marked off on the wall of the dark room on the side where the light is secured (see Fig. 205), or a meter stick for the purpose may be held in the hand of the observer or his assistant.

The method of obtaining the point of reversal at points other than the regulation 1 meter requires such an amount of extra measuring and computing that it does not meet with the general favor and satisfaction accorded to that found by producing an artificial myopia of 1 diopter. This can best be explained by reference to Fig. 204, where, if the observer is at 1-meter dis-

tance, and the neutralizing lens in front of the patient's eye focuses the emergent rays *about* that distance, he may have the liberty of moving forward or back 5 in. (a play of 10 in.) in looking for the point of reversal, and not make a possible error in his result of more than $^{12}/_{100}$ (0.12) of a diopter; *whereas* if he was working closer than this, say at ½ meter, and was moved forward or backward 5 in. to find the point of reversal, he would likely make an error of 0.5 D., or even more, if he was not extremely careful in measuring the distance at which he found the reversal point.

FIG. 204.—Showing distance from patient's eyes in inches and the equivalent in diopters.

Arrangement of Patient, Light, and Observer.—This has already been described in great part, but reference to the accompanying sketch may give the student a more exact appreciation of the arrangement than any lengthy description could do.

For the convenience of the beginner in using the mirror, it is best, as here shown, to keep the surgeon's eye, the light, and the patient's eye on a horizontal line, and to accomplish this in children they will either have to stand, sit on a high stool, or on the parent's lap. The beginner will find it sufficiently difficult at first to reflect and keep the light on the patient's eye with the mirror held perpendicularly, without inclining it up or down, as he would have to do if the arrangement suggested is not carried out. Placing the light to one side of the patient's head, or above it (Fig. 206), and the observer seated

at 1 meter distance from the patient, is a convenient way of working retinoscopy. It has two advantages: the observer avoids the heat of the flame, and at the same time does not have to move the light. But the writer is not partial to this mode of procedure, for various reasons of precision, explained in the text.

Reflection from the Mirror.—The rays of light coming from the round opening in the screen to the plane mirror

FIG. 205.—Arrangement of patient, light, and oculist.

are reflected divergently, as if they came from the opening in the screen situated just as far back in the mirror as they originally started from in front (see Figs. 221, 223 and 225), and the patient, looking into the mirror, sees a round, bright spot of light, corresponding to the opening in the screen (Fig. 210).

How to Use the Mirror.—It should be held firmly before the right eye (Figs. 207 and 208) so that the sight-hole is opposite to the observer's pupil; and that it may be steady, the second

phalanx of the thumb should rest on the cheek just below the eye, the edge of the metal disc even touching the side of the nose if the observer's interpupillary distance is not too great. Thus held in position, its movements should be very limited, though they may be slow or quick, but *never*, at any time, should it be tilted more than 1, 2, or even 3 mm.; for if inclined *more* than this the light is lost from the patient's eye. If the light, the patient's, and the observer's eyes are on a horizontal

FIG. 206.—Light above patient's head and oculist at 1 meter distance.

line, then to find the patient's eye with the reflected light all the observer has to do is to reflect the light back into the light-screen, and by rotating the mirror to his right, carry the reflected light around on the same horizontal line until the patient's eye is reached. This may seem like a superabundance of instruction, but the finding of the patient's eye, which appears so easy, is an immense stumbling-block, at the beginning, to most students. Another way to find the eye is for the observer to hold his left hand up between his and the patient's eye and reflect the light

on to it, and when this is done to drop his hand and let the light pass into the observed eye. Having succeeded in finding the patient's eye, the observer, if he is not very careful in his limited movements of the mirror and himself, will turn the light from the eye almost before he knows it, and so be compelled to start and find it again; this causes much loss of time. A little practice on the schematic eye will assist the beginner

FIG. 207.—Mirror held correctly before right eye and oculist keeps both eyes open.

wonderfully and give him courage, for if he hastens to the human eye, and then has to stop every minute or so to try and get the light on the eye, he soon becomes discouraged and shows his want of experience to the patient.

What the Observer Sees or the General Appearance of the Reflection from the Eye.—With the mirror held before his eye, and close up to the bright light coming from the 10-mm. *opening in the* light-screen, the observer will obtain a reflection

from the pupillary area of the patient's eye which varies in different patients, and is subject to certain changes in the same patient as the refraction is altered by correcting lenses, or it may be changed by the turning of the patient's eye, or lengthening the distance between the mirror and the light, or increasing or diminishing the strength of the light, or increasing the distance between the observer and the patient. The reflection

FIG. 208.—Correct position for mirror but there is no necessity to squeeze the left eye shut after having located the patient's eye.

from the eye of the albino or blond is much brighter than from the brunette or mulatto, in whom it is not so bright, even dim. This character of the reflex is controlled, of course, in great part by the amount of pigment in the eye ground; however, in most instances, there is more or less of a yellowish-red color to the reflex, and this is especially so as the point of reversal is approached; at the point of reversal, however, the reflex becomes less brilliant and possesses something of the color of a piece of

newly coined silver. Cases of high errors of refraction give a dull reflex (see Fig. 219) as compared to low errors, where the reflex is usually *very* bright (see Fig. 211). Should the media be irregular or not perfectly clear, the reflex is altered accordingly; this will be referred to under the head of Irregular Astigmatism. The observer will also notice on the cornea and

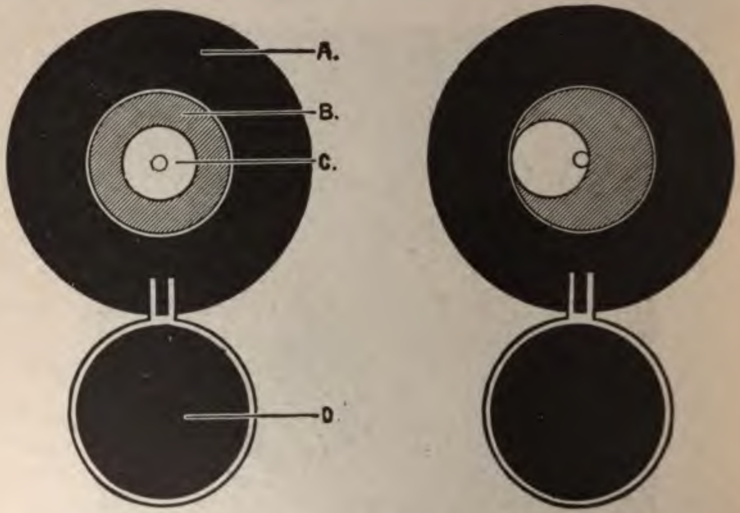


FIG. 209. FIG. 210.

Author's mirror with folding handle.

FIG. 209.—Showing central light C, on small mirror B. This is the light the patient sees when looking into the mirror, and corresponds in size to the 1-cm. opening in screen. D is the folding cap handle to protect B when not in use. A is the metal disc.

FIG. 210.—Shows the light moved to one side as a result of tilting the mirror.

lens bright pin-point catoptric images, and at the inner edge of the iris, in many eyes, a very bright ring of light (see Fig. 211) about 1 mm. in width, which is due to the very strong peripheral refraction; and as the eye is being refracted and the point of reversal approached, this peripheral ring may develop into a broader ring of aberration rays, which at times will be annoying. *This will be referred* to under Spheric Aberration, Chapter XV.

Retinal Illumination.—By holding a strong convex lens closer to or further from a plane surface than its principal focus, or at the distance of its principal focus, and letting the sun's rays pass through it, there will be seen on the plane surface a round area of light; it is this light area which corresponds to the illumination on the retina, seen in retinoscopy by reflecting the light from the mirror into the patient's eye, and hence it is spoken of as the retinal illumination, the "illuminated area," "the area of light," "the image," etc.

Of course, the form of this illumination is controlled, in great part, by the refraction of the patient's eye.

FIG. 211.

FIG. 212.

FIG. 211.—Uniform illumination in an emmetropic eye with slight spheric aberration.

FIG. 212.—Uniform illumination as in Fig. 13, passed to the left by rotating the mirror, darkness or shadow following.

Shadow.—This is the non-illuminated portion of the retina immediately surrounding the illumination. The retinal illumination and shadow are, therefore, in contact, and the contrast is most marked and easily recognized when the refractive error is moderately high 1, 2, or 3 diopters. It is by this combination of the illumination and non-illumination (shadow) that we study and give the "shadow test" its name. In the dark room, the patient keeping his eye fixed, the retina is stationary and in total darkness, except the portion illuminated by the light from the mirror (see Fig. 211). If the mirror be tilted the retinal illumination changes its place (see Fig. 212) and darkness, or shadow, appears in its stead. It is by this change of shadow (darkness) for illumination that we often speak of a movement of the shadow.

Where to Look and What to Look for.—With the patient, the observer, and the source of light in position as directed, the rays of light are reflected into the eye from the mirror as it is gently tilted in various meridians, and the (1) *form,* (2) *direction, and* (3) *rate of movement* of the retinal illumination are carefully noted through a 4- or 5-mm. area *at the apex of the cornea,* as *this* is the part of the refractive media in the normal eye that the patient will use *when* the effects of the cycloplegic pass away and the pupil regains its normal size.

The 1- or 2-mm. area at the edge of the pupil should be avoided by the beginner, except in special instances, as only too frequently it contains a bright ring of light which may or may not give a stronger refraction than the 4-mm. area about the apex of the cornea (see Spheric Aberration, Chapter XV).

The beginner will do good work with the retinoscope if he observes closely the illumination at the center of the pupil and *avoids* looking for shadows.

CHAPTER XIII

POINT OF REVERSAL.—TO FIND THE POINT OF REVERSAL.—WHAT TO AVOID.—DIRECTION OF MOVEMENT OF RETINAL ILLUMINATION.—RATE OF MOVEMENT AND FORM OF ILLUMINATION.—RULES FOR LENSES.—MOVEMENT OF MIRROR AND APPARATUS

Point of Reversal.—This may be defined in several ways—namely: It is the far-point of a myopic eye, or

The artificial focal point of the emergent rays of light (Fig. 222), or

The point where the emergent rays cease to converge and commence to diverge, or

The point conjugate to a point on the retina (Fig. 83), or

The point where the erect image ceases and the inverted image begins, or

The point distant from the eye under examination, where the retinal illumination cannot be seen to move, when the mirror is being tilted.

The point of magnification.

To Find the Point of Reversal.—The recognition of the point of reversal is *the principle* of retinoscopy. It is what is sought for, and, when obtained under certain definite arrangements, is the correct solution of the test. During the test it is easy to tell when the illumination moves with or opposite to the movement of the light on the face, but to get the exact point where there is no apparent movement is not always easy, and the ability to quickly find this point of reversal is acquired only after careful practice.

For example, having determined at 1 meter that the retinal illumination with a +1.50 D. in front of the observed eye just

moves with the light on the face, and against with a +1.75 D., we know that the reversal point must be obtained with the lens numbered between the strength of these two lenses, *i.e.*, +1.62 D. This demonstrates how we arrive at the exact correction, and also the capability and accuracy of retinoscopy.

Emmetropic and hyperopic eyes, in a state of rest, emit parallel and divergent rays, respectively, and to give such eyes a point of reversal, or a focus for the emergent rays, it will be necessary to intercept these rays with a convex lens as they leave the eye. In other words, emmetropic and hyperopic eyes must be made (artificially) myopic. In myopic eyes, however, the emergent rays always focus at some point inside of infinity, and the observer may, therefore, if he is so disposed, by moving his light and mirror toward or away from the patient's eye, as the case may be, find a point where the retinal illumination ceases to move. If this should be at 2 meters, the patient would have a myopia of 0.50 D.; if at 4 meters, a myopia of 0.25 D.; if at 1 meter, a myopia of 1 diopter, if at ½ meter, a myopia of 2 diopters, if at 10 in., a myopia of 4 diopters, etc.

It is well for the beginner to remember, when using the plane mirror, that the illumination *on the patient's face always moves in the same direction the mirror is tilted*, but *not* necessarily so in the pupillary area, where it may appear to move opposite; and *here* it is that we speak of the retinal illumination moving with or against (opposite to) the movement of the mirror, as the case may be, and make our diagnosis accordingly.

As the rays of light from the mirror proceed divergently to the patient's eye, as if they came from a point back in the mirror equal to the distance of the light (opening in light-screen) in front of it and working at 1 meter's distance; with source of light 5 in. in front of the mirror, the rays appear to emerge from a point 5 in. back of the mirror, or a total distance of 45 in. from the patient's eye, thus giving the rays of light a divergence equal to 0.87 diopter before they reach the patient's eye, and this *point may be made* conjugate to the retina. The observer will

do good work if he reduces the retinal illumination to the utmost limit where it can be faintly seen moving with the movement of the mirror, and *if* this is done, the observer's eye and mirror will be just inside of the point of reversal where the erect image can still be recognized. In doing this, however, he must allow 0.87 in his estimate and not 1.00 D.

At the point of reversal no definite movement of the retinal illumination is made out and the pupillary area is seen to be uniformly illuminated, but not so brilliantly as when within or beyond the point of reversal.

If the observer's eye is, at this point, exactly conjugate to the retina, then the movement of the reflected light on the retina cannot be perceived (though it does move), and the retinal illumination will occupy the entire pupil and the shadow will be absent.

Instead, however, of reducing the retinal illumination to the utmost limit (as just mentioned), where it can be faintly seen moving with the movement of the mirror, the writer prefers and recommends placing before the eye under examination such a lens or series of lenses that will bring the emergent rays of light to a focus on his own retina, so that no movement of the retinal illumination can be recognized.

When the point of reversal is approached, the uniform color of the retinal illumination occupies so much of the pupillary area that the student may think he has reached the point of reversal, and if he is not careful to pass the retinal illumination slowly across the pupil and get the shadow, he will find his result deficient, and possibly may also fail to recognize or may miss seeing some small amount of astigmatism.

To make sure that the point of reversal has been obtained, it is always best, especially for the beginner, to keep putting on stronger neutralizing lenses until he gets a *reversal* of movement, when he knows at once that the point of focus of the emergent rays has passed in between the mirror and eye under examination.

The lenses which control the rays of light emerging from the patient's eye are spoken of as neutralizing lenses.

What to Avoid.—It occasionally happens that a retinal vessel or vessels or a remnant of a hyaloid artery, if present, or even the nerve head, may be seen when the light is reflected into the eye; if so, they are to be ignored, as they are not parts of the test. If the patient's eye is turned, or the rays from the mirror fall obliquely, or the neutralizing lens in front of the eye is inclined instead of being perpendicular, there will be seen reflections of light and images upon the neutralizing lens or cornea, or both, and, in consequence, the retinal illumination is more or less hidden or obscured; these images and reflections can be easily corrected by removing the cause. The catoptric images cannot be removed, but as they are very small, the beginner soon learns to ignore them. The retinal illumination may occasionally contain a small dark center, which will disturb the beginner unless he remembers that it is caused by the sight-hole in the mirror, and is most likely to occur when the sight-hole is large and cut through the mirror. This same dark center in the illumination is also seen at times when the light is removed some distance from the mirror, and the correcting lens almost neutralizes the refraction. The neutralizing lens should never be so close to the eye that the lashes touch, and, in warm weather especially, moisture from the patient's face may condense on the trial-lens, and temporarily, until it is removed, obscure the reflex.

Retinoscopy with a Plane Mirror at One Meter's Distance and Source of Light Close to the Mirror.—Direction of Movement of Retinal Illumination.—Apparent Rate of Movement and Form of Illumination.—These important points in reference to the retinal illumination should be decided promptly and without any prolonged examination. This proficiency, of course, will come only by practice, and if, on first examination, the observer cannot decide whether the retinal illumination is *moving with* or opposite to the movement of the reflected light

on the face, he may approach the eye until this point is determined. At the distance of 1 meter the three important essentials may be stated in the following order and in the form of rules:

Direction of Movement of Retinal Illumination.—The recognition of the direction that the retinal illumination takes when tilting the mirror is a most important point in the study of retinoscopy.

The movement of the retinal illumination, when rotating the mirror, going *with* the movement of the light on the patient's face, signifies emmetropia, hyperopia, or myopia, if the myopia is *less* than 1 diopter.

The apparent movement of the retinal illumination going *opposite* to the movement of the light on the face always signifies myopia of *more* than 1 diopter.

Rate of Movement.—This, of course, is under the control and is influenced in great part by the rate of movement of the mirror itself; yet after a little practice the observer will recognize the fact that there is a certain slowness in the apparent rate of movement of the illumination when the refractive error is a high one and requires a strong lens for its neutralization, whereas when the retinal illumination appears to move fast, the refractive error is but slight, and requires a weak lens for its correction.

Form of Illumination.—A large, round illumination, while it *may* signify hyperopia or myopia alone, yet it does not preclude astigmatism in combination.

When the illumination appears to move *faster* in one meridian than the meridian at right angles to it, astigmatism will be in the meridian of *slow* movement. If the retinal illumination is a band of light extending across the pupil, it signifies astigmatism.

The width of the band of light does not indicate so much the strength of the correcting cylinder required for its neutralization as does the apparent rate of movement if slow, a strong, if fast, a weak, cylinder is required.

The meridian subtended by the band of light that is seen when a

spheric lens of 1 *diopter or more corrects one meridian and the meridian at right angles remains partly corrected, indicates the axis of the cylinder in the prescription.*

Rules for Placing Neutralizing Lenses.—A *plus* lens is required when the retinal illumination moves *with* the illumination on the face, and a *minus* lens is required when it moves *opposite* to the light on the face.

Movement of the Mirror.—There are times when a quick movement of the mirror, and, at other times, a slow or gradual movement is required. A substitution of the quick when the slow movement is necessary, then the refraction cannot always be accurately determined. This is explained under "slow movement."

FIG. 213.—Straight edge, indicating astigmatism.

FIG. 214.—Crescent edge, indicating spheric correction.

A quick movement of the mirror may be used when looking into the eye before any correcting lens has been placed *in situ.* It often tells the character of the refraction.

The slow movement of the mirror and the 5-mm. opening in light-screen come into use and are of the *utmost* importance when the eye has been corrected to within 0.75 D. or less, as it is generally at this point that so many, by a *quick* movement, hasten the peripheral rays and mask the central illumination, giving the idea at once of over-correction (see Spheric Aberration, Chapter XV). This is a most common error with the beginner, the inexperienced, and with those who fail to get good results and who ridicule retinoscopy as "not exact," or as "not agreeing with the subjective method." It is well in *every* instance, when the point of reversal is approached, to pass the retinal illumination (not the light area on the face) well

across the pupillary area to make *sure* in regard to the character of shadow which follows or precedes it. This movement, at such a point in neutralization, will often give a hint as to the presence of astigmatism or not, as a reference to Figs. 213 and 214 will show. The presence of astigmatism is known by the straight edge of the illumination, or, in its place, a crescent edge would mean a spheric correction.

Apparatus for Placing Lenses in Front of the Patient's Eye.—There are several different forms in the market, their purpose being twofold—to save time and any extra movements on the part of the surgeon. Of these, that of Würdemann (*American Journal of Ophthalmology*, page 223, 1891) seems the best hand skiascope. A reference to the sketch (Fig. 215) shows this instrument with its convenient handle wherewith the patient, being instructed, raises or lowers the disc in front of the eye, with its smooth broad edge resting against the side of the nose.

FIG. 215.—Würdemann's disc.

One column contains plus and the other minus lenses, and as it is reversible, these may be placed in front of the eye, as the surgeon directs.

The most modern and complete revolving skiascopic disc is that of Jennings (Fig. 216) (*American Journal of Ophthalmology*, November, 1896, and April, 1899), and may be best understood from his own description: "It consists of an upright metal frame, 18 in. high and 7 in. wide, placed at the end of a table 26½ in. long and 12 in. wide. In the upright frame is an endless groove containing 39 lenses and 1 open cell. At the lower end of the frame is a strong driving wheel connected with a horizontal rod running the length of the table to a handle with which the operator rotates the lenses. Facing the operator

and close to his hand is a large disc, on which is indicated the strength of the lens presenting at the sight-hole. The white numbers on a black ground represent convex, and the black numbers on the white ground concave, lenses. The lenses range from 0.25 D. to 9 D. plus, and from 0.25 D. to 9 D. minus. The sight-holes are ⅞ in. in diameter, and are placed about 5 in. from the top of the upright frame. In front of each sight-

FIG. 216.—Jennings' skiascopic disc.

hole is a cell marked in degrees to hold stronger spheres or cylinders. The central portion of the upright is cut away, leaving a space for the face of the patient. A movable blinder is hung from the top, while the chin-rest moves up and down on two parallel rods and is held in place by a thumb-screw. The whole is mounted on a strong adjustable stand, which is raised or lowered by means of a rack and pinion." The essential advantages of this skiascope are as follows:

1. It saves time and fatigue in changing lenses.

2. It is *under the immediate control of the operator*, and indicates the lens in front of the sight-hole without his getting up.

FIG. 217.—Author's trial-frame with axonometers attached. (Drawing reduced in size.)

3. The mechanism is simple, durable, and easy to operate.

4. The cornea is accurately centered and the lens perpendicular to the front of the eye (a very important consideration, and one not possible with *every* kind of trial-frame).

5. The instrument is of such length that the operator is always 1 meter distant from the patient.

FIG. 218.—Author's trial-case for retinoscopy.

While either the hand or the revolving disc is recommended, yet the writer is partial to an accurately fitting trial-frame (Fig. 98), using the lenses from the trial-case, which should be conveniently at hand. The following suggestions in the selection and use of the trial-frame are offered: The temples should rest easily on the ears, the nose-piece (bridge) to have a sufficiently long post to permit the eye-pieces to fit high and accurately over any pair of eyes, especially those of children, and have the cornea occupy the center of each eye-piece. Correct results

cannot be expected or quickly obtained unless the neutralizing lenses be placed with their centers corresponding to corneal centers, and at the same time perpendicular to the front of the eye. A convenient and small trial-case containing a row of plus and minus spheres, from 0.12 to 10 D., is shown in Fig. 218.

CHAPTER XIV

RETINOSCOPY IN EMMETROPIA AND THE VARIOUS FORMS OF REGULAR AMETROPIA.—AXONOMETER

Hyperopia.—In this variety of refraction the direction of the movement of the retinal illumination is *with* the movement of the light on the patient's face. By reflecting the light through the various meridians and observing the rate of movement, a

FIG. 219.

FIG. 220.

FIG. 219.—Gray reflex as seen in high hyperopia, even darker than the picture shows it.

FIG. 220.—Gray reflex with crescent edge by tilting mirror to left, darkness or shadow following.

strong or weak plus sphere, according to the apparent rate of movement, is placed before the eye and the rate of movement of the retinal illumination is again noted.

Practice alone will guide the observer in a quick appreciation of the approximate strength of neutralizing lens to thus employ.

If the movement of the illumination appears slow, and the observer places a +2.75 D. before the eye for its neutralization, and the illumination then becomes brilliant and appears to move fast and with the light on the face, the hyperopia is still slightly uncorrected and a stronger lens must be substituted. (At this point in the examination the 5-mm. opening in the light-screen may be used to advantage.)

Removing the +2.75 D. and substituting a +3.25 D., if the

retinal illumination is then found to move *opposite* to the movement of the light on the face, the refraction of the eye will then be represented by the lens numbered between the +2.75 D. and the 3.25 D., which is 3 D (see example, page 206, Chapter XIII). Now, while the +3 D. has brought the emergent rays to a focus at 1 meter, it has made the eye myopic just 1 diopter, so that in taking the patient from the dark room to test his vision at 6 meters, or infinity, this 1 diopter (artificial myopia) must be subtracted from the +3 D., which would leave +2 D., the amount of the hyperopia.

A reference to Fig. 222 will illustrate the description just given.

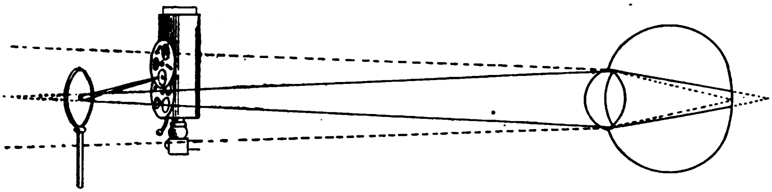


FIG. 221.

Figure 221 is the hyperopic eye under examination, and shows the mirror at 1 meter's distance, with the light 5 in. from the mirror. The dotted lines represent the rays proceeding divergently from the eye under examination; the dark lines show the reflected rays from the mirror, which illuminate the retina and have an imaginary focus (dotted lines) beyond the retina.

Figure 222 is a profile view showing the hyperopic eye with neutralizing lens in position. The dotted lines with arrowheads indicate the direction the rays would naturally take coming from the eye. The lens (+3 D.) in front of the eye is just sufficiently strong to bend these divergent rays and bring them to a focus at 1 meter's distance (artificial point of reversal). In other words, +2 D. of the 3 diopters thus placed before this hyperopic eye would have bent the divergent rays and made *them parallel,* or emmetropic, but the additional 1 diopter bends

the rays still more and brings them to a focus (P.R., point of reversal) at 1 meter. If, now, with the +3 D. before the eye, the observer approaches the eye thus refracted and observes the retinal illumination closer than 1 meter, he will be inside of the point of reversal, and consequently see an erect image moving rapidly with the direction of the movement of the mirror. If beyond this point of reversal (P.R.), he would get an inverted image and the retinal illumination moving rapidly in a direction opposite to the movement of the mirror.

Emmetropia.—The emergent rays from an emmetropic eye are always parallel, and the observer seated at 1 meter sees the pupillary area in such an eye brilliantly illuminated, the illumi-

FIG. 222.

nation moving rapidly with the light on the face as the mirror is slowly tilted.

A reference to Fig. 223 shows the emmetropic eye under examination with the position of light, mirror, and eye, as in Fig. 221. The dotted lines indicate the parallel emergent rays, and the solid lines the divergent rays from the mirror with an imaginary focus just beyond the retina. The purpose in this instance, as in all others of retinoscopy, is to place such a neutralizing lens before the eye as will bend the emergent rays and bring them to a focus at a certain definite distance, making the emergent rays from a point on the retina come to a focus on the observer's retina. Therefore, to change this illumination so that no movement can be seen to take place in the pupillary area, and at the same time have the emergent rays focus on the observer's retina, a +1 sphere must be placed before the eye.

Just here the writer wishes to *impress* upon the beginner the great importance, as mentioned on page 195, of refracting the macular region. To accomplish this, the patient must fix his gaze upon the metal disc or letters on the disc of the mirror. As the region of the macula is departed from, the strength of the neutralizing lens grows slightly stronger in emmetropia and hyperopia, and diminishes in myopia. A reference to Fig. 224 will give an idea of what is meant, and show that radii drawn from the nodal point are all shorter than the one to the fovea.

Myopia.—In myopia the emergent rays *always* converge to the far-point (point of reversal), and the observer, seated at 1 meter distant from the eye, will have the apparent movement

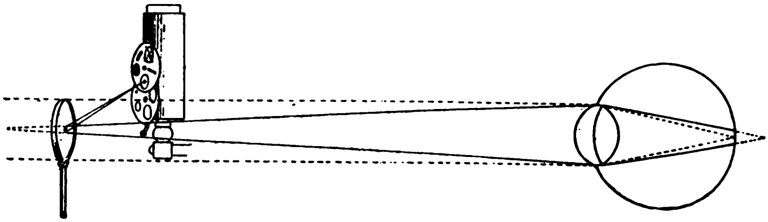


FIG. 223.

of the retinal illumination going opposite to the light on the face *if* the myopia exceeds 1 diopter, and *with* the light on the face *if* the *myopia* is less than 1 diopter. If the myopia should be *just* 1 diopter, then the emergent rays would focus on the observer's retina at 1 meter, and there will not be any neutralizing lens required to accomplish this purpose; but if the emergent rays focus beyond 1 meter, the observer will be within this point of reversal or focus, and will, therefore, have an erect image, moving fast with the movement of the mirror, and will have to place before the eye a plus lens of less than 1 diopter to bring the point of reversal up to the distance of 1 meter. When the myopia is more than 1 diopter, and observer at 1 meter, the emergent rays will have focused somewhere between the observer and the patient and, as a result, the retinal illumination appears

to move opposite to the light upon the face, more or less rapidly according to the amount of myopia, and a concave or minus lens must be placed in front of such an eye that will bring the emergent rays to a focus at 1 meter, or, in other words, will stop all apparent movement of the retinal illumination. If, for example, a −2.75 D. has been so placed and the movement is still slightly opposite to the movement of the mirror, and a −3.25 D. substituted makes the retinal illumination move *with* the movement of the mirror, then the neutralizing lens for 1 meter will be numbered between −2.75 D. and −3.25 D., which will be −3 D.

Figure 225 shows the myopic eye just described, with the position of the mirror, light, and eye as in Figs. 222 and 225. The solid lines represent the rays reflected divergently from the mirror focusing at a point in the vitreous before coming to the retina, and the broken lines show the rays emerging from a point on the retina and then converging to the focus, far-point, or point of reversal close to the eye, between the eye and the mirror. The observer, seated with the mirror 1 meter distant, gets an opposite movement in the pupillary area from the direction in which he moves his mirror, and, of course, an inverted image. If the observer had his eye at the point where the emergent rays focused (dotted lines cross), he would not recognize any movement in the pupillary area, and it would have a uniform reflex. The amount of the myopia is equal to the distance measured from this point of reversal to the cornea; for example, if the distance (point of reversal) was 25 cm. from the patient's eye, then the amount of the myopia would be 4 diopters; if at 33 cm., then 3 D., etc.

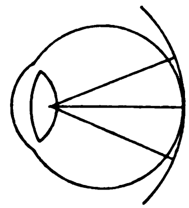


FIG. 224.

Figure 226 is a profile view of the myopic eye. The dotted lines show the rays coming from a point on the retina and focusing at the far-point (F.P.); the solid lines show the emergent rays acted upon or bent by a planoconcave lens of 3 diopters,

which has lessened the convergence of these emergent rays and put the far-point farther from the eye, or at a distance of 1 meter. The observer at this distance does not appreciate any movement in the pupillary area, but if he moves the light and mirror closer to the eye he is then inside the point of reversal and gets an erect image moving with the movement of the mirror; if beyond the 1 meter's distance, an inverted image and movement against the movement of the mirror will be seen. If a −4 D. lens had been placed before this myopic eye, the emergent rays would have proceeded from it parallel, and the observer, at 1 meter, would have the same conditions as in the refraction of an emmetropic eye, Fig. 223; but as only a −3 D.

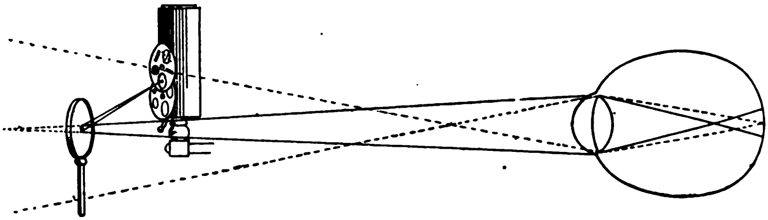


FIG. 225.

glass was used, the eye has 1 diopter of its myopia uncorrected. From the description of retinoscopy in hyperopia, emmetropia, and myopia, just given, the student will recognize at once that the hyperopic, emmetropic, and myopic eyes of less than 1 diopter, working with the plane mirror at 1 meter's distance, are given a stronger refraction than they naturally call for, or, in other words, are made artificially myopic 1 diopter. And the myopic eye of more than 1 diopter, under similar conditions, being already myopic, retains 1 diopter of its myopia. To give a patient thus refracted with the retinoscope his emmetropic correction (correction for parallel rays of light), *an allowance must always be made, in all meridians, of 1 diopter, no matter what the refraction.* The artificial myopia thus produced at 1 meter gives the following rules for glasses required for infinity:

Rules.—1. When the neutralizing lens employed is plus, then subtract 1 diopter.

2. When the neutralizing lens employed is minus, then add a −1 D., or what is more simple, or even a better rule, is to *always add a −1 sphere to the neutralizing lens obtained in the dark room when working at 1 meter, and the result will be the emmetropic or infinity correction.*

Examples:

Dark Room	+0.50	0.00	+1.00	+2.00	−1.00
Adding	−1.00	−1.00	−1.00	−1.00	−1.00
Emmetropic Correction	−0.50	−1.00	−0.00	+1.00	−2.00

The main point in all retinoscopic work to remember, in changing from the dark room to the 6-meter correction, is to always allow for

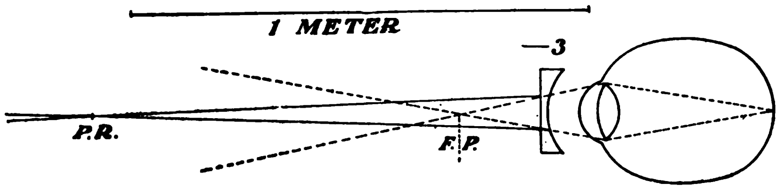


Fig. 226.

the distance from the patient's eye to the point of reversal—i.e., if working at ½ meter, allow 2 diopters; if at 2 meters, 0.50 D., if at 4 meters, 0.25 D., etc.

Regular Astigmatism.—When refracting with the retinoscope, the observer should remember *that he is refracting, the meridian in the direction of which he moves the mirror.* Particular attention is called to this important fact on account of the confusion sometimes arising in the student's mind from the use of the ophthalmoscope, where the refractive condition of a certain meridian is estimated by the strength of the lens used to see clearly the vessels at right angles to it. Astigmatism being present in an eye means a difference in the strength of the glass

required for the two principal meridians, which, with few exceptions, are at right angles to each other, and it is to these two principal meridians *only* that the observer pays attention; for example, the eye that takes the following formula,

+1.00 D. $\bigcirc$ +1.00 cyl. axis 105°,

means that in the 105 meridian there is +1 D. and in the 15 meridian a +2 D. In the dark room a +2 sphere in front of such an eye at 1 meter would correct the 105 meridian and partly correct the 15 meridian; or a +3 D. would correct the 15 and over-correct (movement against) the 105 meridian. When with +2 D. the 105 meridian is corrected and the 15 only partly so, there is seen in the 15 meridian a band of light which stands or extends across the pupil in the 105 meridian and moves across the pupil from left to right *with* the movement of the mirror as the light is reflected through the 15 meridian.

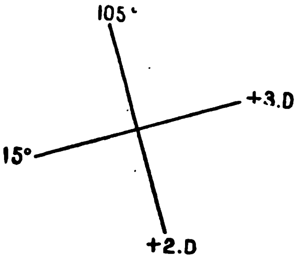


FIG. 227.

The presence of this band of light *after* the meridian of least ametropia has been corrected *always* signifies astigmatism, and the axis it subtends—in this case 105°—gives the axis of the cylinder in the prescription; and the amount of the astigmatism, or the strength of the cylinder required, is the difference between the strength of the two spheres employed. Figure 227 shows the method of writing such a dark-room correction, and adding, according to our rule, a −1 to this dark-room work, we get our original formula:

+1.00 D. $\bigcirc$ +1.00 cyl. axis 105°.

The method of correcting with spheres (Fig. 218) will be found much more satisfactory than by placing a +2 D., as called for in the 105 meridian, then adding and changing cylinders until the correct one is found. It takes much time and care to get the cylinder axis just right, and is most difficult in the dark

room. After the result has been obtained with spheres, the observer may, if he is so disposed, prove it before leaving the dark room with the sphero-cylinder combination.

Astigmatism may or may not be recognized on first inspection of the fundus-reflex, this depending *entirely* on the refraction; if it be a high astigmatism with a small amount of refractive

FIG. 228. FIG. 229.

FIG. 228.—Band of light at axis 60°, with the 60° meridian neutralized. No movement of the illumination can be recognized in the 60° meridian.

FIG. 229.—Shows the same as Fig. 228, but the band of light with straight edge has been moved upward and to the left by tilting the mirror in the 150° meridian.

error in the opposite meridian, as in one of the following formulas,

$$+1.00 \text{ D.} \subset +3.00 \text{ cyl. axis } 45^\circ,$$
$$-1.00 \text{ D.} \subset -4.00 \text{ cyl. axis } 180^\circ,$$

then the band of light so characteristic of astigmatism will be plainly seen on first inspection, extending across the pupil before any neutralizing lens has been placed in position; but if the hyperopia or myopia be high and the cylinder required is low, as in one of the following formulas,

$$+3.00 \text{ D.} \subset +0.75 \text{ cyl. axis } 105^\circ,$$
$$-4.00 \text{ D.} \subset -1.00 \text{ cyl. axis } 165^\circ,$$

then the band of light is not recognized on first inspection or until an approximate correction has been placed before the eye. To get an idea of what the band of light looks like, the beginner may refer to Figs. 228 and 230; or focus rays of light through a strong cylinder; or place a + or − 2 D. cyl. in front of the schematic eye registered at zero and study the retinal illumination. The student should bear in mind that the band of light appears on the meridian of least ametropia, and is brightest when this

meridian has received its full spheric correction—the opposite meridian being only partly corrected.

The reason for the brightness of the band of light when the meridian of its axis is corrected is that any point on the retina in this meridian is conjugate to the focus on the observer's retina (point of reversal), and any movement of the mirror in this meridian is not recognized, but has a uniform color and occupies the entire meridian of the pupil. To recognize so small an error as a quarter diopter cylinder—which is *not* easily detected, and the observer, if he is in a hurry, might think the case one of simple hyperopia or myopia—the writer would suggest that when the supposed point of reversal is reached the correcting sphere be increased ¼ diopter, and *if* only one meridian is found over-corrected (movement opposite), the other remaining correct (no movement recognized), he *then* knows that a quarter cylinder is required; for example, a +2 D. is supposed to correct all meridians, and yet by substituting a +2.25 D., the vertical meridian moves against and the horizontal remains stationary; then a +0.25 D. cyl. is called for at axis 90°.

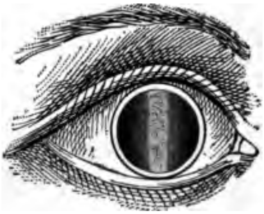


FIG. 230.—Band of light astigmatism axis 90°.

Cases having a low astigmatic error of 0.50 D. can be recognized when near the point of reversal by the faint shaded area on each side of the band of light, as shown in Fig. 231—a condition often overlooked.

Mixed Astigmatism.—In this condition of refraction, where one meridian is myopic and the meridian at right angles to it is hyperopic, the movement of the retinal illumination in the myopic meridian will be controlled by the *amount* of the myopia. The illumination in the myopic meridian, if the myopia is less than 1 diopter, moves *with* the mirror, and against the movement of the mirror if it is more than 1 diopter; in either instance *the observer* gets a distinct band of light in the meridians

alternately as each meridian is neutralized separately with a sphere. Taking the following example (no glass in front of the

$$-2.00 \text{ cyl. axis } 180° \supset +1.00 \text{ cyl. axis } 90°,$$

eye), the 90 meridian shows an *opposite* movement up and down, and in the horizontal the movement is *with* the movement of the mirror. If, now, a -1 D. sphere is placed before the eye, the 90 meridian is neutralized for 1-meter distance, and a bright band of light is seen at 90°, moving with the movement of the mirror in the horizontal meridian. Removing the -1 D. and placing a $+2$ D. before the eye, which would neutralize the horizontal meridian for 1 meter, a bright band will be seen in the horizontal meridian and moving opposite to the movement of the mirror in the 90° meridian. Carrying out the rule of always adding a -1 D. sphere to the correction obtained in the dark room at 1 meter, we have -1 added to the -1 in the vertical meridian, making -2 D. axis 180°; and adding -1 to the $+2$ D. in the horizontal, we have $+1$ D. axis 90°, or our original formula.

FIG. 231.—Band of light showing half a diopter of astigmatism.

$$-2.00 \text{ axis } 180° \supset +1.00 \text{ cyl. axis } 90°.$$

The rule for neutralizing lenses in mixed astigmatism is the same as for any other form of refraction, namely, using a plus lens when the movement is with, and a minus lens when the movement is opposite to, the movement of the light on the face.

To transpose crossed cylinders into a sphero-cylinder combination the writer would advise using the rule of Dr. Harry S. Pearse, of Albany, which is as follows:

"The cylinder is the sum of the two cylinders with the sign and axis of one of the cylinders. The sphere is the strength of the other cylinder with its sign." In the above formula, the sphero-cylinder combination will be

$$-2 \text{ D.} \supset +3.00 \text{ cyl. axis } 90°.$$

Axonometer.—To find the exact axis subtended by the band

of light while studying the retinal illumination, when the meridian of least ametropia has been corrected, the writer has suggested a small instrument which, for want of a better name, he has called an axonometer.

FIG. 232.

The original description of this device was published in *The Medical News*, March 3, 1894, as follows: "The direction of the principal meridians of corneal curvature is often difficult to determine, and the statement of the patient must be accepted when confirming the shadow-test correction; or, if there is still uncertainty, the ophthalmometer of Javal may be of service. The axonometer is a black metal disc, with a milled edge, 1½ mm. in thickness, of the diameter of the ordinary trial-lens, and mounted in a cell of the trial-set. It has a central round opening 12 mm. in diameter—the diameter of the average cornea at its base.

FIG. 233.

Two heavy white lines, one on each side, pass from the circumference across to the central opening, bisecting the disc. *To use* the axonometer, place it in the front opening of the trial-*frame, and* with the patient seated erect and frame accurately

adjusted so that the cornea of the eye to be refracted occupies the central opening, proceed as in the usual method of making the shadow test. As soon as that lens is found which corrects the meridian of least ametropia and the band of light appears distinct, turn the axonometer slowly until the two heavy white lines accurately coincide, or appear to make one continuous line with the band of light (see Fig. 232).

FIG. 234.—Trial-frame with axonometers in position indicating symmetric astigmatism.

"The degree marks on the trial-frame to which the arrowhead at the end of the white lines then points is the exact axis for the cylinder. The axonometer possesses the following points of merit:

"Simplicity.

"Accuracy.

"Small expense.

"It covers an unnecessary part of the trial-lens which too frequently gives annoying reflexes and images.

"It saves time, avoids the statement of the patient, and renders the ophthalmometer unnecessary.

"Its color (black) absorbs the superfluous light rays from the mirror and gives a stronger contrast to the reflex and central illumination.

FIG. 235.—Trial-frame with axonometers in position indicating asymmetric astigmatism.

"Limiting the field of vision in children, it permits of more concentrated attention.

"For children and nervous patients, when it is difficult to use the ophthalmometer, this simple appliance is of great service."

Lately the writer has improved the axonometer by having *the white lines* broadened to 4 mm., which is a decided advan-

tage over the instrument shown in Fig. 232 as the broad line is easily seen at 1 meter distance. This axonometer, shown in Fig. 233, is made of thick celluloid.

Figure 234 shows the trial-frame with axonometers in position indicating symmetric astigmatism.

Figure 235 shows the trail-frame with axonometers in position indicating asymmetric astigmatism.

CHAPTER XV

RETINOSCOPY IN THE VARIOUS FORMS OF IRREGULAR AMETROPIA.—RETINOSCOPY WITHOUT A CYCLOPLEGIC.—THE CONCAVE MIRROR.—DESCRIPTION OF THE AUTHOR'S SCHEMATIC EYE AND LIGHT-SCREEN.—LENSES FOR THE STUDY OF THE SCISSOR MOVEMENT, CONIC CORNEA, AND SPHERIC ABERRATION

Irregular Astigmatism.—This condition is either in the cornea or in the lens, or in both structures in one and the same eye; in any instance it is confusing to the beginner, and even the expert must work slowly to obtain a definite result. The corneal form is most difficult to refract as the retinal illumination is more or less obscured by areas of darkness. The illumination between these dark areas appears to move with, in places, and in others against, the movement of the mirror. By moving the mirror so as to make the light describe a circle around the pupillary edge, a most unique kaleidoscopic picture is obtained, which is quite diagnostic of the condition. To refract an eye with this irregularity the observer may have to change his position several times, going closer to or farther away from the patient. Very often these eyes are astigmatic, and the band of light may be promptly noted by the observer changing his position as suggested, and at the same time placing a neutralizing lens before the eye. Care *must* be taken, also, to refract in the area of the cornea that will correspond to the small pupil when the effect of the cycloplegic passes away. It is wise in these cases of irregular corneal astigmatism, to make a record of the correction found and use it as a guide in a postcycloplegic *manifest* refraction.

Irregular astigmatism of the lens is frequently more or less uniform, and not so broken as in the corneal variety. Figure 236 shows irregular lenticular astigmatism, with spicules pointing in from the periphery, and so long as these do not encroach upon the pupillary area, they do not usually in themselves interfere with vision; they are not often recognized until the pupil is dilated, are then very faint, and not usually made out until the point of reversal is approached. Irregular lenticular astigmatism, when *just* beginning, is very seldom seen with the ophthalmoscope; the striations are too fine to be made out except under the conditions just described, and when recognized are of inestimable value from a point of prophylactic treatment, calling for a change of occupation, rest to the eyes, and carefully selected glasses, the latter often being weak lenses. These lenticular conditions not infrequently accompany the "flannel-red" fundus, the "fluffy eye ground," the "shot-silk retina," the "woolly choroid," etc.

FIG. 236.—Irregular lenticular astigmatism.

Scissor Movement.—Another form of astigmatism that may be classed as irregular is where there are two areas of light, each with a straight edge, and usually seen on the horizontal meridian, or inclined a few degrees from the horizontal, and moving toward each other as the mirror is tilted in the opposite meridian; in other words as the observer is seated at 1 meter he sees an area of light above and an area of light below with a dark interspace (Fig. 238). As the mirror is slowly tilted in the vertical meridian these light areas approach and are followed by darkness or shadow, and at the same time the dark interspace begins to fade, the light areas are brought together and result in a horizontal band of light, as seen in Fig. 239, and at this point

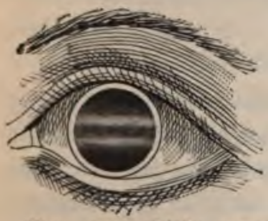


FIG. 237.—Light areas coming together and dark interspace fading.

resemble the ordinary band of light as seen in regular astigmatism. This movement of the light areas is likened to the opening and closing of the scissor blades, and hence the name of scissor movement.

These cases are more or less difficult to refract, but the presence of the two areas of light with the dark interspace will often assist in a correct selection of glasses, for while they are generally of the compound hyperopic variety, calling for a plus sphere and plus cylinder, yet practice and the patient's statement often call for a plus sphere and minus cylinder.

With the following formula,

$$+2.00 \text{ D.} \bigcirc +0.75 \text{ cyl. axis } 90°,$$

substituting a sphere the strength of the combined values of the sphere and cylinder, and using a minus cylinder of the same

Fig. 238.

Fig. 239.

Fig. 238.—Light area above and below, with dark interspace.
Fig. 239.—Light areas brought together.

number as the plus cylinder at the opposite axis, the result will be,

$$+2.75 \text{ D.} \bigcirc -0.75 \text{ cyl. axis } 180°.$$

The vision with the latter formula is much better in many instances than with the former, and though either formula would be correct, yet the latter is practically the better of the two, and should be ordered when so found. The writer's method of procedure when he recognizes the scissor movement is to tilt the mirror until the two light areas are brought into one band of light as shown in Fig. 239 and then to reflect the light through the meridian of this band (in this instance as illustrated, the 180 meridian). Having obtained the lens which neutralizes *the movement* in this meridian, the writer does not attempt to

find the neutralizing lens for the opposite meridian but goes from the dark room to the trial-case and places before the patient's eye that sphere which corrects the refraction in the horizontal meridian. For instance, if +3.75 D. corrects the horizontal meridian at 1 meter, then +2.75 D. sphere is placed before the eye, and a minus cylinder (beginning with −0.50 at axis 180°) is placed in front of the sphere and the strength of this minus cylinder is gradually increased so long as the visual acuity improves. In other words the writer does not attempt to estimate the refraction with the retinoscope in the meridian opposite to the bands of light. The condition which may be the probable cause of the scissor movement is a slight tilting of the lens (see Fig. 240)—that is, the anteroposterior axis of the lens is not at right angles to the plane of the cornea, thus making one portion of the pupil myopic (area of light moving opposite) and the other portion hyperopic (area of light moving with the movement of the mirror). This condition may be simulated by placing a convex lens at an angle before the schematic eye, or reflecting the light into the eye obliquely, or by using the combination lens in front of the schematic eye, as suggested on page 239.

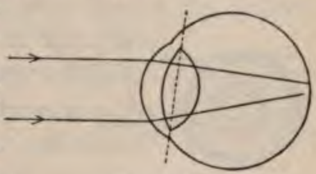


FIG. 240.

What causes the tilting of the lens the writer is not prepared to state *positively;* it may be congenital, and yet careful inquiry of the patients, in many instances, has shown that it is most likely due to using the eyes to excess in the recumbent posture. It may be a coincidence, but most of the cases of scissor movement seen by the author have been in adults, and those who were in the habit of reading while lying down, reading themselves to sleep at night in bed.[1] Other cases were seen

[1] The writer does not wish to be misunderstood and does *not* say that every one who uses his eyes in this faulty position *must* develop this form of irregular astigmatism.

among paper-hangers, whose occupation compelled them to look upward much of the time. These do not seem unlikely causes, especially when the anatomy of the ciliary region is considered, the strain of the accommodation (possibly spasm) during the faulty position of the eye tilting the lens as it rests upon the vitreous body. This form of astigmatism, so far as known, remains a permanent one even after a cessation from the original cause and correcting glasses have been ordered. The retinoscope is the only instrument of precision we have in diagnosing this condition. The ophthalmoscope may recognize the presence of the astigmatism, but not its character, and the ophthalmometer only records the corneal curvature. Cases of aphakia (following cataract *extraction*) frequently show the scissor movement *during* the process of retinoscopy. This is undoubtedly due to the flattening of the cornea corresponding to the section, making one portion myopic and the other hyperopic. Figure 241, with correcting sphere in position, shows such a condition, where the upper illumination would move with and the lower, being myopic, would move against the movement of the mirror.

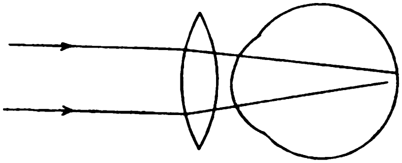


FIG. 241.

Compound Irregular Astigmatism.—This is a combination of the scissor movement and regular astigmatism, but they are *not* at right angles to each other. The scissor movement may be at 180°, and the regular astigmatism at some point *away* from 90°, but not at 90°; or the regular astigmatism may be at 90° and the scissor movement at some meridian other than 180°.

A hasty review of the literature of astigmatism does not reveal any reference to this form, and the name for the condition has been suggested by the following picture, namely: When studying the reflex, a vertical band of light will be seen passing across the *pupillary area* from left to right as the mirror is turned, and

then in the vertical meridian (*not* at right angles) the scissor movement will be recognized also; there is, therefore, a combination of regular corneal astigmatism with the scissor movement at an oblique angle, giving the compound name suggested. This form of astigmatism is rare, yet not difficult to diagnose or refract when understood. It is hoped, however, that the beginner in retinoscopy may not meet one of these on his first attempt at the human eye (see page 240).

Conic Cornea.—Reflecting the light into an eye that has such a condition, the observer is impressed at once with the bright central illumination that moves opposite to the movement of the mirror, the peripheral illumination moving with, unless perchance the margin should be myopic also, but of less degree. This form of illumination is seen in Fig. 242, showing the central illumination faintly separated by a shaded area or ring from the peripheral circle. The best way to refract a case of this kind is to keep a record of the neutralizing lens or lenses required for the portion of the pupillary area that will correspond to the size of the pupil after the effect of the cycloplegic passes away, and use this record as a guide in a post-cycloplegic manifest correction, as in irregular corneal astigmatism.

FIG. 242.—Illumination seen in conic cornea.

As the apex of the cone is not always central, the observer must not expect to always find the bright illumination in the center of the pupillary area, as just mentioned; and it is also well to note the fact that a band of light will often appear during the process of neutralization, as astigmatism is usually present. This is further described on page 239.

Spheric Aberration.—This appears under two forms, positive or negative, and is the condition in which, during the process of neutralization, there are two areas, one central and the other peripheral, where the refraction is not the same. In positive aberration the peripheral refraction is stronger and in negative aberration the peripheral is weaker than the central area; that

is to say, in the positive form, when the point of reversal for the center of the pupil is close to 1 meter, the peripheral illumination grows broader and has a tendency to, and often will, crowd in upon the small central illumination, giving the idea of neutralization, or even the appearance of over-correction, the illumination in the periphery moving opposite. The observer must be on his guard for this condition, and while giving the mirror a

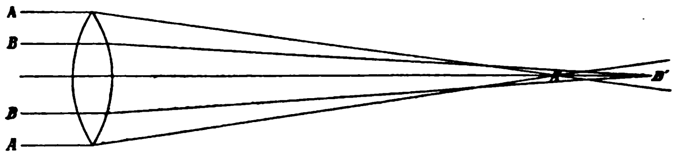


FIG. 243.—Positive aberration.

slow and limited rotation must watch carefully the illumination in the center of the pupil and *not* hasten the peripheral movement (see What to Avoid, Chapter XIII). The observer may have to approach the patient's eye closer than 1 meter if the peripheral illumination appears to move very fast. The negative form is where the peripheral refraction is weak as compared to the central which appears strong, and when the neutralizing

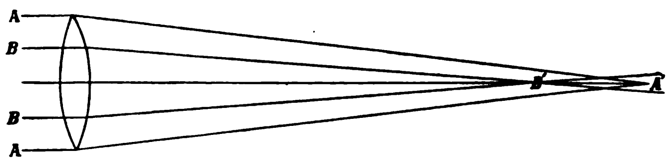


FIG. 244.—Negative aberration.

lens gives a point of reversal to the center of the pupil the peripheral illumination still moves with the movement of the mirror. This condition is seen in cases of conic cornea.

Figure 243 illustrates positive aberration where the parallel rays passing through a convex lens in the periphery at AA come to a focus at A′, much sooner than the parallel rays BB, near the center, which comes to a focus back of A′ at B′.

Figure 244 illustrates negative aberration, which is the reverse of positive aberration, and the central rays BB are focused at B′ in front of the peripheral rays AA focusing at A′.

Retinoscopy without a Cycloplegic.—Cases of myopia and mixed astigmatism which have large pupils *can* be quickly and accurately refracted by the shadow test without the use of a cycloplegic. This has been repeatedly proven by comparison of the manifest and cycloplegic results; yet it is not a method to be recommended or pursued, for two reasons: One is that these patients are not annoyed, like hyperopics, by the blurred near-vision incident to the cycloplegic; and, secondly, glasses ordered without the cycloplegic seldom give the comfort that follows from the physiologic rest the eye receives from the drug. The surgeon will obtain much assistance and save time by using the retinoscope in cases of aphakia, in old persons especially who are very slow to answer, and will insist upon a description of what they do and do not see, as also in re-reading the test-card from the very top each time a change of lens is put in the trial-frame. Presbyopes of 50 or more years of age can be quickly and not inconveniently refracted by the shadow test after having their pupils dilated with a weak (4 per cent.) solution of cocain.

Concave Mirror.—While the study of retinoscopy with the concave mirror is not a part of the subject of this book, and allusion to it has been carefully avoided up to this time, yet for the benefit of those who may wish to try it, the writer would suggest that it will be necessary to place the source of light (20- or 30-mm. opening in light-screen) above and beyond the patient's head, 1 meter distant, or more, so that the convergent rays from the mirror come to a focus and cross before entering the observed eye. Then to estimate the refraction, proceed as with the plane mirror, remembering, however, that the movements of the retinal illumination are just the reverse of those obtained when using the plane mirror.

The author's light-screen or cover chimney (see Fig. 202 and the *Annals of Ophthalmology and* Otology, October, 1896)

is made of 1/8-in. asbestos, and of sufficient size to fit easily over the glass chimney of the Argand burner; attached to the asbestos by means of a metal clamp are two superimposed discs, which revolve independently of each other. The lower disc contains a piece of white porcelain, 30 mm. in diameter; also four round openings, respectively 5, 10, 20, and 35 mm. in diameter. The upper disc contains a round 35-mm. opening, a round section of blue cobalt glass, a perforated disc, a vertical and a horizontal slit, each 2½ by 25 mm. The several uses of this screen are as follows:

1. For the ophthalmoscope a good light is obtained by superimposing the two 35-mm. openings.

2. Combining the 35-mm. opening in the upper with either the 5- or 10-mm. in the lower disc, a source of light is produced for the small retinoscope: and,

3. By substituting the 20-mm. opening, light is had for the concave mirror.

4. Placing the cobalt glass over the 5-, 10-, 20-, or 35-mm. opening, and the chromo-aberration test for ametropia is given.

5. To test for astigmatism at 1 meter while using the plane mirror, or for heterophoria at 6 meters, the perforated disc is to be turned over the porcelain, the latter producing a clear white image (page 178).

6. The horizontal slit placed over the porcelain glass, and the operator may exercise the oblique muscles.

7. The vertical slit similarly placed gives the test for paralyzed muscles.

Lenses for the Study of the Scissor Movement, Conic Cornea, Spheric Aberration, and Lenticular Astigmatism.— (Described by the author in the *Journal of the American Medical Association*, December 18, 1897.)

As the scissor movement, conic cornea, spheric aberration, and lenticular astigmatism, as recognized by the retinoscope, are so difficult of demonstration, except in the individual patient *the writer has* suggested and had made four lenses which will

illustrate these conditions respectively when placed in front of his schematic eye; and thus the beginner in retinoscopy may have the opportunity to see, know, and study these important and interesting manifestations (and at small expense) before proceeding direct and in comparative ignorance to his patient.

Figures 245 and 248 represent a plano-concave cylinder of 2 diopters, mounted in a cell of the trial-case, and to one-half of its plane surface is cemented (at the same axis) a plano-convex cylinder of 4 diopters, thus making a combination lens, one-half of which is a -2 D. and the other half equaling a $+2$ D. Placing this lens, with its axis at 180°, before the schematic eye

FIG. 245.

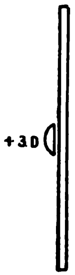


FIG. 246.

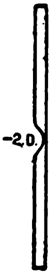


FIG. 247.

at emmetropia (zero), and the observer at 1 meter distance with his plane mirror, the two light areas characteristic of the scissor movement, with their comparatively straight edges and dark interspace may be seen approaching each other from above and below (and the dark interspace disappearing) as the mirror is tilted in the vertical meridian.

Figures 246 and 249 represent a section of thin plane glass mounted as in Fig. 245 and has cemented at its center a small plano-convex sphere of 3 diopters, whose base is about 4 mm. in diameter. Placing this lens in front of the schematic eye at emmetropia, and reflecting the light from the plane mirror at 1 meter, there will be seen in the pupillary area a small central illumination, which moves against or opposite to the movement of the mirror, and at the same time there will also be seen a

peripheral ring (at the edge of the iris) which moves rapidly with the movement of the mirror; between these light areas is a shaded ring of feeble illumination. This is the retinoscopic picture and movement of the light areas, so indicative of conic cornea. It is also an exaggerated picture of negative aberration.

Figures 247 and 250 represent a section similar to that shown in Fig. 246 and 249, except that at its center is ground a −2 D. sphere of about 4 mm. in diameter. To produce spheric aberration of the positive form, place this lens in front of the schematic eye at emmetropia, and the observer, seated at 1 meter

FIG. 248.

FIG. 249.

distance with the plane mirror, will see in the pupillary area a central illumination which moves slower than the peripheral area or ring (at the edge of the iris), which moves rapidly, both areas moving with the movement of the mirror. Figure 251 shows a lens for studying lenticular astigmatism. This is made by scratching a piece of plane glass with a diamond.

After the observer has carefully studied these pictures it will be obvious that changes other than those mentioned can be made with these lenses, and he should proceed to note them by—

1. Changing the focus of the schematic eye.
2. By varying his distance from the eye.
3. By placing both the concave and convex spheres in *combination.*

4. By placing a concave cylinder in front of the double cylinder at an oblique axis, thus getting a picture of compound irregular astigmatism.

5. By placing a concave cylinder in front of the convex sphere and developing astigmatism with the conic cornea, which is the usual condition; or a convex cylinder might be used in place of the concave cylinder if a higher error is desired.

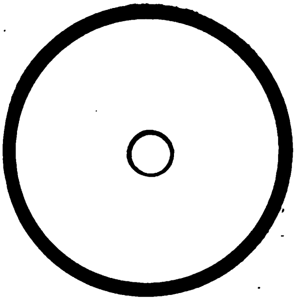


FIG. 250.

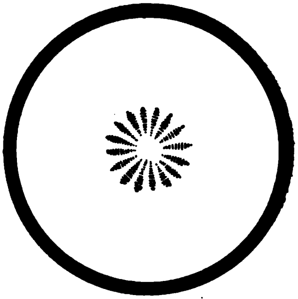


FIG. 251.

6. It is obvious, also, that the scissor movement can be produced by a prism which is made to cover one-half of the pupillary area, but the resulting picture is not so satisfactory for demonstration as that given by the combination lens referred to in Fig. 245.

CHAPTER XVI

MUSCLES

Examination of the External Eye Muscles

General Considerations.—When the retinal image of an object is situated exactly on the fovea, the eye is said to "fix" the object.

Normally, when both eyes "fix" the object, each eye has an image of the object on its fovea, and these foveal images or impressions are transmitted to the brain and fused as one image in the visual centers. This condition is spoken of as equipoise, or orthophoria, and the eyes are said to be in equilibrium, or to balance. Whenever one eye alone fixes an object, and the fellow eye receives the image of the same object on a part of its retina distant from the fovea, then the brain takes note of two separate impressions, and this condition is spoken of as double vision (diplopia). When the retinal impression of the nonfixing eye is very close to its macula, the patient is frequently conscious of blurred vision and muscular effort to make the eye fix; in other words, the patient has headaches, usually occipital, together with a soreness of the eyeball, etc.

(*a*) The image of an object formed upon the retina above the fovea is projected downward; *i.e.*, objects situated below the horizontal line of vision are recognized by that portion of the retina above the fovea.

(*b*) The image of an object formed upon the retina below the fovea is projected upward; *i.e.*, objects situated above the horizontal line of vision are recognized by that portion of the retina below the fovea.

(*c*) The image of an object formed on the retina to the nasal

side of the fovea is projected toward the temporal side; *i.e.*, objects to the temporal side have their images formed upon the nasal portion of the retina.

(*d*) The image of an object formed on the retina to the temporal side of the fovea is projected toward the nasal side; *i.e.*, objects to the nasal side have their images formed upon the temporal portion of the retina.

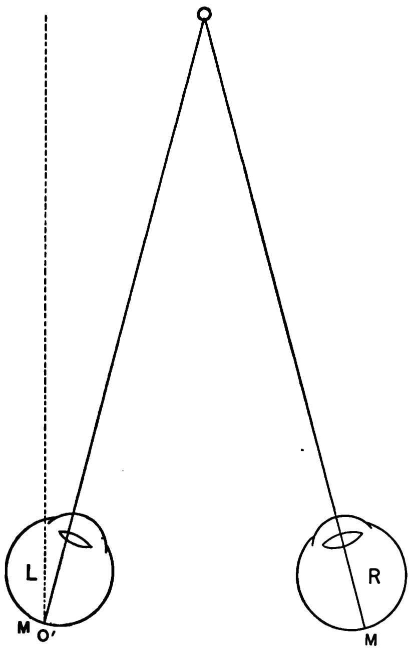


FIG. 252.

Homonymous Diplopia (Greek, ὁμώνυμος; from ὁμὸς, same, and ὄνυμα, name).—Figure 252 shows the right eye (R) fixing upon the object (O), but the left eye is turned inward, so that rays from O fall upon its retina to the nasal side of the fovea (M), and are projected outward to the temporal side; the result is that the left eye sees a false object to the left of the real ob-

ject. This condition of the objects is spoken of as homonymous diplopia.

Heteronymous Diplopia (Greek, ἕτερος, other; and ὄνυμα, name).—Figure 253 shows the right eye fixing the object (O), but the left eye is turned outward, so that rays from O fall upon the retina to the temporal side of the fovea and are projected

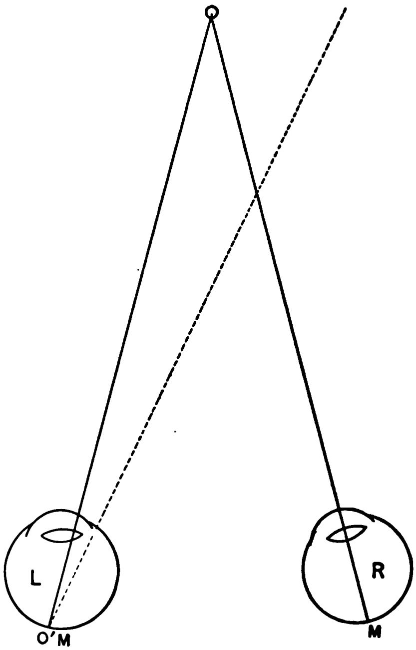


FIG. 253.

to the nasal side, with the result that the left eye sees a false object to the right of the real object. This condition of the objects is spoken of as heteronymous or crossed diplopia.

Hypertropia (Greek, ὑπ ρ, over, above; τροπή, to turn).—In the consideration of vertical diplopia—which is always a condition of crossed vertical diplopia, never homonymous vertical diplopia—the eye which is deviated upward is spoken of as the *hypertropic eye,* and necessarily its image must be lower than

its fellow. For instance, if the left eye fixes an object and the right eye is turned upward, the rays of light from the object would fall upon the upper part of the retina of the right eye, and would be projected downward below the true object; and this position of the right eye is spoken of as right hypertropia. Or if the right eye fixes an object and the left eye sees a false object below, then the position of the left eye is spoken of as left hypertropia. Unfortunately, in hypertropia the position of the eyes does not tell whether the right superior rectus is too strong and the left inferior rectus too weak, or the left superior rectus too weak and the right inferior rectus too strong.

Muscle Phorometry.—Testing the power of the ocular muscles.

Abduction.—The power of the external recti muscles to turn the eyes outward. The patient is comfortably seated and told to look at a point of steady light at a distance of about 6 meters, slightly below the level of his eyes, never above the level. In this position prisms with their bases inward are placed in front of one or both eyes until the patient says he sees two lights in the horizontal plane and very close together. The strength of the prism or prisms thus placed before the eyes which will just permit the eyes to see one object and if increased would produce diplopia, represents the power or innervation of the external recti muscles. This is spoken of as the power of abduction, and is abbreviated Abd. For example, if with 7 centrads, base in, before the eyes there are two lights, and with 6 centrads there is only one light, then 6 centrads would represent the amount of the abduction. In other words, in the case supposed, as long as there is less than 7 centrads before the eyes, base inward, the external recti muscles can overcome their effect, but as soon as a prism stronger than 6 centrads is used, then the external recti muscles cannot counteract the effect, and diplopia is the result.

Adduction.—The power of the internal recti muscles to turn the eyes inward. The power of the internal recti is tested in the

same way as the external, except that the prism is placed base outward. This is spoken of as adduction, and is abbreviated Add. For example, if with 19 centrads, base out, before the eyes two lights are seen in the horizontal plane and with 18 centrads only one light, then 18 centrads represent the power of adduction. In other words, as long as there is a prism of 18 or less than 18 centrads before the eyes, base outward in this case, the internal recti muscles can overcome the effect; but as soon as a prism stronger than 18 centrads is used, then the internal recti muscles cannot counteract the effect, and diplopia is the result. It must be remembered that the internal and external recti are antagonistic, and that the muscles of the two eyes are tested together. The relative power of adduction to abduction has been variously estimated, but most authorities are agreed that adduction is about three times that of abduction, or about 3 to 1—that is to say, in eyes with normal muscle balance, if adduction is represented by 18 centrads, then abduction should be 6; or if adduction is represented by 24 centrads, then abduction should be 8 centrads; or if adduction is 12 centrads, then abduction should be 4 centrads, etc.

The statement that adduction is three times as great as abduction in standard eyes applies particularly to patients who pursue close occupations, whereas those who pursue an occupation that requires distant vision, sailors, soldiers, etc., may have adduction of only twice that of abduction and yet have what may be termed standard extra-ocular muscles. A close occupation, reading, writing, sewing, etc., develops the adducting power, and this is quite necessary at any prolonged close work.

Sursumduction.—This is the power of the eyes to fuse two images when one eye has a prism placed base up or down before it. For example, if a 3½-centrad prism is placed base up or down before either eye and diplopia results and persists, and then a 3-centrad is substituted and there is no diplopia, then the eyes have overcome the effect of the prism and the amount

of the sursumduction is said to be 3 centrads. This test for sursumduction is made at the same distance as in testing the lateral muscles. In health the power of the superior and inferior recti muscles is, as a rule, the same; that is to say, they antagonize each other equally. Supraduction (sursumvergence) is the turning of the eyes upward by contraction of the superior recti and inferior obliques. Infraduction (deorsumvergence) is turning the eyes downward by contraction of the inferior recti and superior obliques.

Muscular Imbalance.—Whenever there is any disturbance in the power, strength, or innervation of the ocular muscle or muscles, the condition is no longer one of equipoise, or equilibrium, or muscle balance, but is spoken of as muscular imbalance (heterophoria). From this statement it must not be supposed that the two eyes cannot simultaneously "fix" an object, any more than it must be supposed that a hyperopic eye cannot see or have $\frac{VI}{VI}$ vision without correcting glasses.

Just as in hyperopia distant vision may be made clear by the effort of accommodation, so in muscular imbalance the visual axes can be directed to one point of fixation by increased innervation. Muscular imbalance is subdivided into two classes—insufficiency and strabismus.

The following nomenclature of muscular anomalies, suggested by Stevens, of New York, is in common use:

Orthophoria, perfect muscle balance, equipoise, or binocular equilibrium.

Orthotropia, perfect binocular fixation.

Heterophoria, imperfect binocular balance, or imperfect binocular equilibrium.

Heterotropia, a squint or decided deviation or turning from parallelism.

Hyperphoria, a tendency of one eye to deviate upward.

Hypertropia, a deviation of one eye upward.

Esophoria, a tendency of the visual axes to deviate inward.

Esotropia, a deviation of the visual axes inward.

Exophoria, a tendency of the visual axes to deviate outward.

Exotropia, a deviation of the visual axes outward.

Hyperesophoria, a tendency of the visual axis of one eye to deviate upward and inward.

Hyperesotropia, a deviation of the visual axis of one eye upward and inward.

Hyperexophoria, a tendency of the visual axis of one eye to deviate upward and outward.

Hyperexotropia, a deviation of the visual axis of one eye upward and outward.

Cyclophoria, an insufficiency of an oblique muscle.

The above nomenclature is descriptive of a symptom only and does not signify which eye is at fault, for instance hyperphoria means that the visual axis of one eye tends to deviate above that of its fellow without indicating or specifying which is the faulty eye, or if we speak of left hyperphoria we do not signify whether the left elevators or the right depressors are too strong or whether the left depressors or the right elevators are weak.

Insufficiency.—Also called latent deviation, heterophoria, or latent squint. This may be defined as the condition in which there is a tending or *tendency* of the visual axes to deviate from the *point of fixation;* this may be slight or transitory (Figs. 254 and 255).

Causes of Insufficiency.—The chief cause of insufficiency is some form of ametropia. Another cause may be an anatomic defect of one or more of the ocular muscles themselves, or a weakness of the muscle or muscles individually, or as a result of some systemic weakness. The ocular muscles often sympathize with the economy. Adenoids, inflammation and disease of the tonsils, disease of the sinuses, turbinals, polypi, teeth, rheumatism, etc., are some of the causes to be looked for.

Symptoms of Insufficiency, or Muscular Asthenopia.—Accommodative and muscular asthenopia are intimately associated, and the latter is so often the companion of the former that

they produce symptoms which are identical in both and make it difficult to draw any sharp line of demarcation between the two. In muscular asthenopia, however, the patient complains that the eyes "become weak" or "tired" after any prolonged use, and that this is especially apt to occur by artificial light; that nearby objects (reading, writing, or sewing) grow dim; that the words "seem to jump," or the "letters run together," and in some cases occasionally, and in others more frequently,

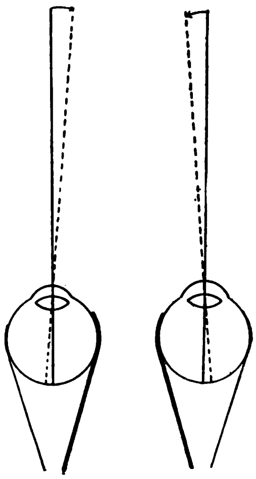


FIG. 254.—Tendency of visual axes inward.

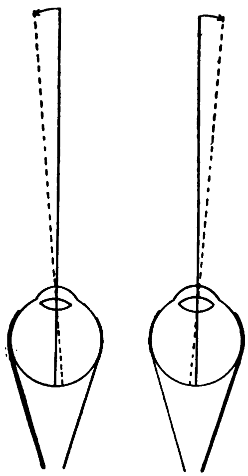


FIG. 255.—Tendency of visual axes outward.

objects appear double for a moment. Sometimes one of the eyes feels as if it was turning outward or inward. There are innumerable reflex symptoms, dizziness, nausea, vomiting, fainting, and, in some instances, "all becomes dark for a minute." Such patients often become very anxious, fearing sudden blindness, etc.

Diagnosis or Tests for Insufficiency (Heterophoria).—Before taking up the individual tests for insufficiencies, it is well for the observer to study the movements or excursions of the eyes; and to do this the patient, with his head erect and steady in one

position, fixes with his eyes the point of a pencil held in the hand of the observer at about 13 in. distant. The pencil is moved from left to right and from right to left, and upward and downward; as this is done, the surgeon should watch closely to see that each eye has a normal mobility and the two eyes move together. From a central point of fixation the eyes should move inward about 45°, outward 45° or 50°, upward about 40°, and downward about 60°. The tropometer of Stevens will estimate the limit of motion of each eye separately, but if there is a defect in mobility, the surgeon may recognize it by comparing the distance of the corneal edge in each eye from a certain definite fixed point; for instance, whether the lid margins encroach equally upon the cornea or have equal intervals between cornea and lid edges.

The Cover Test.—The patient is told to look at the point of a pencil held in the hand of the surgeon on a level with the patient's eyes in the median line, and distant about 18 in., or at an object 6 meters distant. While the eyes fix the point of the pencil or distant object or point of light, the surgeon covers one eye with a small card, and a moment later quickly withdraws it and observes the position and movement of the eye which he has just uncovered; if it moved inward toward the nose to fix the point of the pencil, then there must have been an outward tendency of that eye when under cover; in other words, the external muscles must have been strong or the internal weak. If the eye thus released from the cover had moved outward toward the temple to fix the point of the pencil, then the external recti must have been weak or the internal strong. If the eye released from cover goes up to fix, then the fellow-eye deviates upward, and *vice versa*. This test is not always reliable, and yet it may be a guide to further study.

Parallax Test.—The cover test is an objective test whereas the parallax test is subjective and is executed the same as in making the cover test, the only difference being, that in the *parallax test* the patient states as he looks at the point of light

at 6 meters distance, whether the light appears to move in the same direction as the cover is carried to the other eye (exophoria) or if the light appears to move in the opposite direction (esophoria) and if downward or upward (hyperphoria).

The Fixation Test.—Instead of covering one eye, as in the cover test, the patient "fixes" the point of the pencil as it is slowly advanced in the median line toward the nose, up to within 4 in., if necessary. During this advance of the pencil, if there is a weakness of the interni, the eye with the weaker internus is the one which will usually deviate outward.

Tests for Heterophoria and Heterotropia.—There are many of these tests and each has more or less value. Like the many tests for astigmatism they should be understood and then the reader may decide for himself to use one or more of them as they appeal to his judgment.

Von Graefe Equilibrium Test (Fig. 256, A).—This test is a black dot 1 in. in diameter at the middle of a straight line 12 in. long passing through it, drawn on a white card and hung on the wall 6 meters from the patient's eyes, the dot being on a level with the eyes. This card should be hung in a bright light or illuminated by reflected light. As the patient gazes at this dot and line a 7 centrad prism is placed base down before the left eye. This produces an image of the line and dot upward which belongs to the left eye the lower image belongs to the right eye. If the upper dot is directly above the lower dot and the black lines are superimposed, running through both dots then there is no lateral deviation (Fig. 256, B).

Esophoria.—If, however, the upper dot and line appear to the left (Fig. 256, C) then there is *esophoria* and the amount of the esophoria is represented by the strength of prism placed base outward before the right eye (or the left) which will put the upper dot directly above the lower one as Fig. 256, B.

Exophoria.—If the upper dot and line appear to the right (Fig. 256, D) then there is *exophoria* and the amount of the exophoria is represented by the strength of prism placed base

inward before the right eye[1] (or the left) which will put the upper dot directly above the lower one.

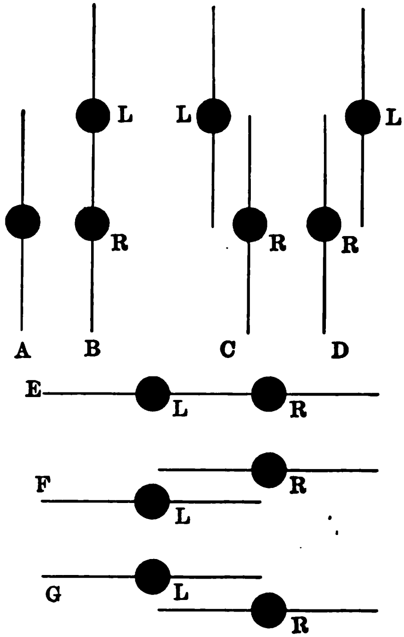


FIG. 256.—Von Graefe line and dot test. A = Line and dot. B = No lateral deviation. C = Esophoria. D = Exophoria. E = No vertical deviation. F = Left hyperphoria. G = Right hyperphoria. L = Image of left eye. R = Image of right eye.

Hyperphoria.—Place a 10-centrad prism base in before the left eye, and have the line and dot placed horizontally. If the eyes see two dots on one line (Fig. 256, E), then there is no vertical

[1] The reader's careful attention is called to the writer's method of making the foregoing test as it is similar to the tests which are to be described; namely, that the right eye is free or unencumbered to fix the object or white light; and the right eye is thus reserved for the use of the correcting prism. Furthermore, the amount of the esophoria is estimated by the prism base out; exophoria by the prism base in; left hyperphoria by the prism base up before the right eye and right hyperphoria by the prism base down before the right eye. Finally, in place of any lengthy description of esophoria, exophoria and hyperphoria as each test is described, the reader is referred to the respective illustrations.

deviation. If the right dot and line appear higher than the left line and dot then there is left hyperphoria (Fig. 256, F). If the right dot and line appear lower than the left line and dot then there is right hyperphoria (Fig. 256, G).

Prism Tests.—Place a 7-centrad prism in the trial-frame or phorometer base down before the left eye as the two eyes look at the point of light as described under Adduction. This prism produces vertical diplopia. The upper light naturally belongs to the left eye under these conditions, and if it is directly above the other, then there is no lateral deviation.

Esophoria.—If the upper light is to the left of the lower, then the condition is one of esophoria and its amount is equal to the strength of the prism placed base outward before the right eye which will bring one light directly above the other.

Exophoria.—If the upper light is to the right of the lower, then the condition is one of exophoria and its amount is equal to the strength of the prism placed base in before the right eye which will bring one light directly above the other.

Hyperphoria.—Place a 10-centrad prism base in before the left eye, then the left light belongs to the left eye. If the two lights then appear in the horizontal meridian there is no vertical deviation. If the left light is lower than the right then there is left hyperphoria. If the left light is higher than the right then there is right hyperphoria.

The amount of the left hyperphoria is represented by the strength of the prism placed base up before the right eye which will bring these two lights exactly horizontal. The amount of the right hyperphoria is represented by the strength of the prism placed base down before the right eye, which will bring these two lights exactly horizontal.

Use of Ruby Red Glass also Cobalt Blue Glass.—To avoid confusion on the part of the examiner and patient in making these tests for esophoria, exophoria and hyperphoria, as is the case when both lights are white, it is decidedly better to use a plane piece of ruby red glass or cobalt blue glass with the prism

over the left eye and in this way the lights seen by the two eyes are quickly differentiated.

In making the above tests, the writer uses a 7-centrad prism, made either of cobalt blue glass or ruby red glass.

Maddox Double Prism (Fig. 257).—(Obtuse-angled prism.) This is two prisms of 6 centrads each with their bases united. Placed before the left eye so that the bases bisect the pupil horizontally, the left eye will see two images, one higher and one lower than the true light seen by the right (fixing) eye.

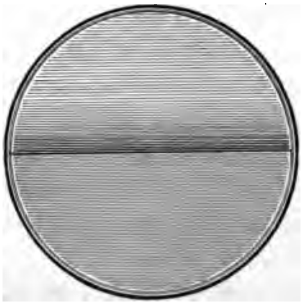


FIG. 257.—Maddox double prism.

Maddox double prism with a piece of ruby red glass or a Maddox Double Prism made of ruby red glass. This is far more attractive and avoids the confusion incident to having the lights all of one color seen by both eyes (Figs. 258 and 259).

Cobalt Blue Glass with the Maddox double prism or the Maddox Double Prism made of Cobalt Blue Glass (Figs. 260 and 261) gives the test as shown in Fig. 262.

The writer has been unable to demonstrate with his own eyes, as some authorities have done, that there is any definite streak of light connecting the two lights produced by the Maddox Double Prism of colored or colorless glass.

Cone or Quadrant or Quadrilateral Prism (Fig. 264).—This is equivalent to a pair of Maddox Double Prisms superimposed, one at axis 90° and the other at axis 180°. Four images of the light are produced (Fig. 263), forming the corners to a square which are connected by a streak of light of the color of the glass. As this is made in colorless glass, it will be of great advantage to combine with it the plane ruby red glass or have the quadrant prism made of ruby red glass.

Fig. 260.

Fig. 261.

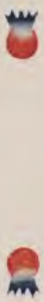


Fig. 262.

Maddox double prism made of cobalt blue glass. Fig. 260 is profile of Fig. 261. Fig. 262 is double image produced by Maddox double prism of cobalt blue glass.

The Author's Double Prism, Truncated[1] (Figs. 265, 266 and 267).—The difficulty experienced by the writer in the use of the

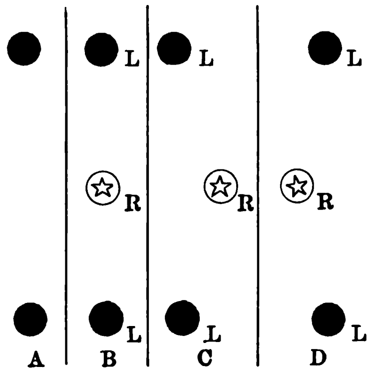


FIG. 258.—Maddox double prism of ruby red glass. A = Two images produced by double prism. B = No lateral deviation. C = Esophoria. D = Exophoria.

obtuse-angled prism in testing for hyperphoria of small amount has been to have patients describe whether the central light

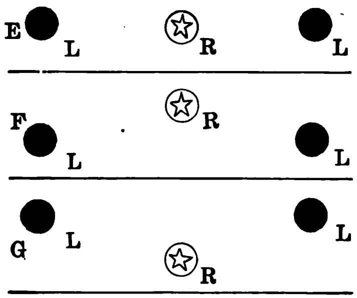


FIG. 259.—E = No vertical deviation. F = Left hyperphoria. G = Right hyperphoria. L = Image of left eye. R = Image of right eye.

seen by the right eye approached the upper or lower images as seen by the left eye. To overcome this difficulty of decision on the part of the patient, the author had the edge or top of the

[1] Shown and described to the Section of Ophthalmology of the College of Physicians of Philadelphia, October 17, 1912.

double prism cut off evenly leaving a flattened top 3 mm. wide, see Fig. 265, making what he has chosen to call a truncated

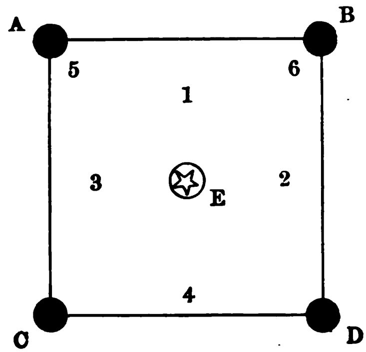


FIG. 263.—Quadrilateral prism or cone in red producing four red images connected by red streaks.[1] E = True light seen by right eye. When E is equidistant from ABCD there is no displacement, hence = Orthophoria. When E is in the direction of 1 = Left hyperphoria; in the direction of 2 = Esophoria; in the direction of 3 = Exophoria; in the direction of 4 = Right hyperphoria; in the direction of 5 = Left hyperexophoria; in the direction of 6 = Left hyperesophoria.

prism.[2] This is made either of ruby red glass, cobalt blue glass or colorless glass. With this form of double prism placed before the eye the observer immediately sees a central true light and an image above and an image below, equidistant from it, if the truncated prism has been accurately ground. These three lights are seen to be connected by a band of light, Fig. 267, and the whole is distinctive from the single white light of the right eye. For the illustrative description of the tests see Figs. 268 and 269, also 270 and 271.

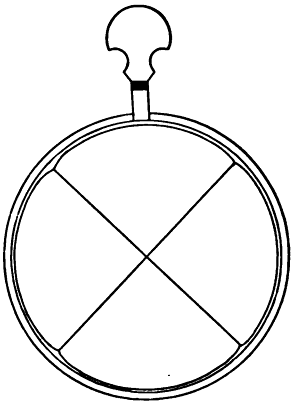


FIG. 264.—Cone or quadrant prism.

Maddox Rod.—This is a single glass rod or a series of glass rods of

[1] See footnote, page 252.

[2] "A cone or pyramid whose vertex is cut off parallel to the base by a plane."

Fig. 265.

Fig. 266.

Fig. 267.

Author's double prism of cobalt blue glass. Fig. 265 is profile of Fig. 266. Fig. 267 is triple images connected by a streak as seen through this double prism.

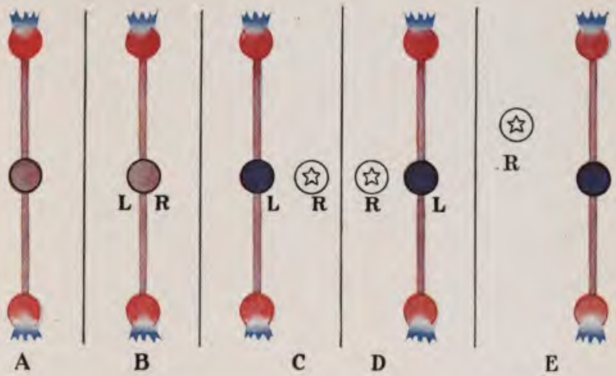


FIG. 268.—Triple images and streak produced by author's double prism in cobalt blue glass. B = No lateral deviation. C = Esophoria. D = Exophoria. E = Left hyperexophoria.

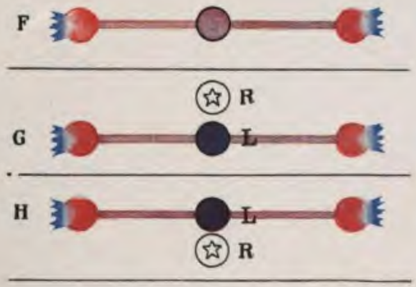


FIG. 269.—F = No vertical deviation. G = Left hyperphoria. H = Right hyperphoria. L = Image of left eye. R = Image of right eye.

red or colorless glass (Figs. 272 and 273) placed in a metal cell of the trial-case, and the eye looking through it at the light will see the image of the light distorted into a streak of

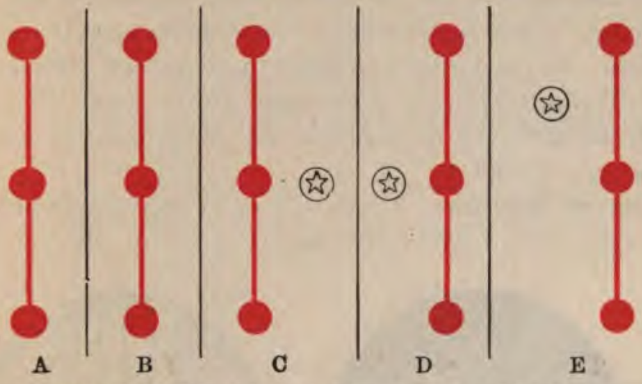


FIG. 270.—Author's double prism of ruby red. A = Three images connected by streak. B = No lateral deviation. C = Esophoria. D = Exophoria. E = Left hyperexophoria.

broken light. A strong + cylinder from the trial-case may be used for the same purpose. As the rod refracts rays of light

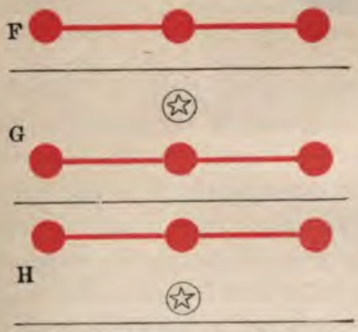


FIG. 271.—F = No vertical deviation. G = Left hyperphoria. H = Right hyperphoria.

opposite to its axis, the eye will see a streak of light in the reverse meridian to that in which the axis is placed. See Figs. 272 and 273, also Figs. 274 and 275.

Maddox Double Prism and Rod Combined.—This produces two streaks of light (Fig. 276, A) white or red as the operator may choose. See illustrations in Figs. 275, 276 and 277. This combination, like the double prism by itself, is not as satisfactory a test for esophoria or exophoria as it is for hyperphoria. In the former condition the right eye will frequently fuse its image with one of the light streaks of the left eye, *i.e.*, with the right one in esophoria and the left one in exophoria (Fig. 276, C and D).

Convex Spherical.—Using a +15 diopter sphere before the left eye a very much blurred image is seen by this eye, and the

FIG. 272.—Maddox rod.

FIG. 273.

position of the image of the right eye relative to this blurred image gives the diagnosis of the muscular imbalance. If the image of the right eye centers on the blurred image, then the condition is one of orthophoria; if to the right or left or above or below the blurred image, then it will be esophoria, exophoria, right hyperphoria or left hyperphoria respectively. However, the writer is not partial to this test, as it is most difficult for the average patient to maintain exact fixation with his left eye.

Tangent Scale and Maddox Rod.—This tangent scale[1] of Prentice (Fig. 56), with a central light as a fixing object and a Maddox rod before the left eye, furnishes an ideal test as the record of the amount of the deviation can be stated by the

[1] *Archives of Ophthalmology*, Vol. XIX, No. 1, pages 64 and 68.

patient. Each line of displacement of the streak is equivalent to 1 centrad or prism-diopter. For example, if the patient states that the streak is situated vertically on the zero line

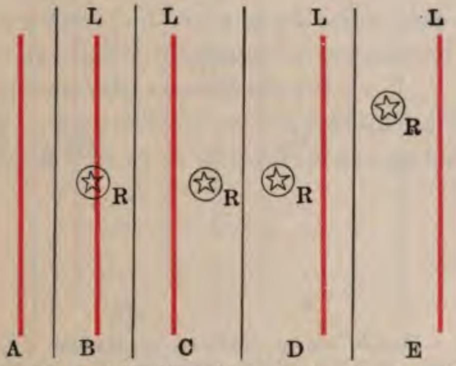


FIG. 274.—A = Image of Maddox single rod in red. B = No lateral deviation. C = Esophoria. D = Exophoria. E = Left hyperexophoria. R = Image of right eye. L = Image of left eye.

there is no lateral deviation; if the streak is situated horizontally on the zero line there is no vertical deviation; if the streak is to the left or right or above or below the zero line then esophoria,

FIG. 275.—F = No vertical deviation. G = Left hyperphoria. H = Right hyperphoria. L = Image of left eye. R = Image of right eye.

exophoria, and right or left hyperphoria are present and to the amount as indicated by the position of the streak, whether on line numbered 1, 2, 3, etc. If the streak is between two lines,

then there is also a fraction of a centrad or prism-diopter of deviation.

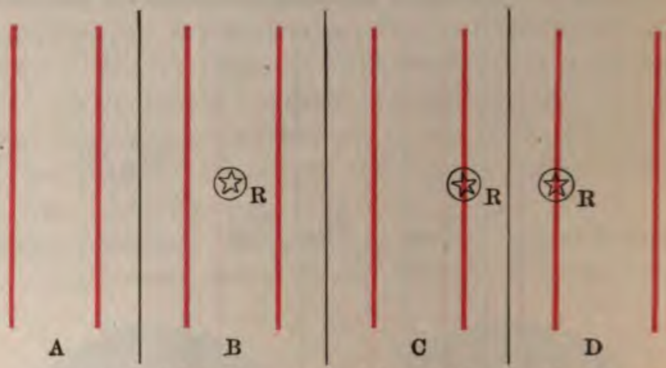


FIG. 276.—A = Double images produced by Maddox double prism in red with Maddox rod. B = No lateral deviation. C = Esophoria. D = Exophoria.

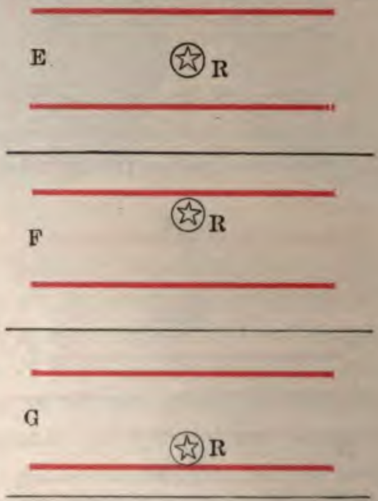


FIG. 277.—E = No vertical deviation. F = Left hyperphoria. G = Right hyperphoria. R = Image of right eye.

Another way to use the tangent squares (Fig. 56) is to place a 7-centrad prism base down before the left eye and in this *way produce* an upper image of the chart. If the upper image

is displaced directly upward with the vertically numbered lines coinciding, then there is no lateral deviation. If the upper image appears to the left the amount of the esophoria is quickly diagnosed and likewise the amount of exophoria if the upper image is to the right. A 10-centrad prism base in axis 180° before the left eye would diagnose the presence of left or right hyperphoria and also the amount of each.

Cyclophoria.—(Insufficiency of an oblique muscle.) This test is usually made at 13 or 18 in. from the patient's eyes. A

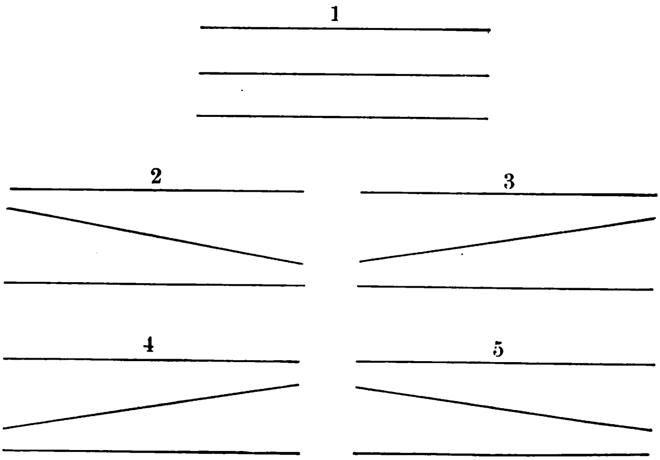


FIG. 278.—Tests for insufficiency of the oblique muscles. 1 = Orthophoria or equilibrium of the obliques. 2 = Insufficiency of left superior oblique. 3 = Insufficiency of right superior oblique. 4 = Insufficiency of the left inferior oblique. 5 = Insufficiency of the right inferior oblique.

narrow straight black line is placed horizontally on a white card as the fixing object at the distance indicated. A Maddox double prism is placed before the left eye so that the bases bisect the pupil horizontally, and this eye then sees two parallel horizontal lines if its oblique muscles are in a standard condition. The right eye sees but one line between the two lines seen by the left eye. The right eye is the one being tested and the position of the middle line furnishes the diagnosis. If the left eye is to be

tested, then the Maddox double prism must be placed before the right eye (Fig. 278).

Cyclophoria and its varieties may also be diagnosed by using two Maddox rods, one at axis 90° before one eye and the other at axis 180° before the other eye, and a point of light as the fixing object at 6 meters. If orthophoria is present the two streaks produced by the two rods will naturally form a cross; but if cyclophoria is present, then one of the streaks will show a tilting or inclination from an otherwise true position of being horizontal or vertical indicating at once, therefore, which eye is at fault or has the oblique insufficiency. Whenever the writer is suspicious of the existence of cyclophoria, he is partial to the use of a colorless rod before one eye and a red rod before the other eye, but each must be placed with its axis exactly horizontal. If the two streaks appear parallel or are superimposed, there is no oblique insufficiency; but if one streak dips, so to speak, then cyclophoria is present and corresponds to the eye having the corresponding rod, the inclination or dip furnishing a prompt diagnosis of the muscle at fault. In making either of these tests extreme care must be exercised to see that the phorometer or trial-frame and patient's eyes are true to the horizontal meridian. **Hyperesophoria and Hyperexophoria** may be diagnosed by any of these tests and are easily recognized as shown in the tests figured in 263 and 268.

While the foregoing tests are used for heterophoria or latent squint, yet they are also used for testing heterotropia or manifest squint. It is not necessary therefore to describe the tests for heterotropia, except to say that when heterotropia is of very high degree and one eye has defective sight, it may be necessary to begin the test with a red glass and strong prism base over the weak muscle of the poor-seeing eye so as to engage its attention.

Other tests for heterophoria and heterotropia are made with the use of apparatus and the following have been selected from several as most worthy of consideration.

Steven's Phorometer (see Fig. 287).—This is composed of two 5-centrad prisms each mounted in a separate large cell with cogged edges; one prism is mounted before each eye and these are connected by a small cogged wheel. A convenient handle on the right cell when pushed to either side makes both prisms revolve at the same rate of speed. The marking on the cell to which the prism pointer is directed indicates the degree and variety of heterophoria. The reader will appreciate the fact that this apparatus is ideal, but its usefulness is limited to errors of 10 centrads. If the operator wishes to use the Steven's phorometer to test errors higher than 10 centrads he must place an additional prism from the trial-case next to one of the patient's eyes. To avoid confusion it might be well to state that these two prisms of the Steven's phorometer never occupy the same position at the same time. They may both be base in or both base out, or one base up while the other is base down. They never reach a point where one is base in and the other base out, or both bases down or both bases up at the same time.

FIG. 279.

The apparatus is used as both eyes are looking at the point of light.

Dr. E. A. Prince's Phorometer (Fig. 279).—This instrument with its convenient handle is for the patient to hold before either eye as directed. A 4-centrad prism and a Maddox rod are enclosed in a metal case. A milled head screw on one side permits the patient or operator to revolve the prism. The patient is told to fix with both eyes on a point of light at 6 meters. If the streak is vertical and to one side of the light, the prism is revolved until the streak and light appear to unite. The scale records the amount and character of the lateral deviation. To

test hyperphoria, the apparatus must be taken off of the handle and replaced with the rod vertical so as to produce a horizontal streak, and then revolve the prism until the streak and light appear to unite. Unfortunately this apparatus is limited in its usefulness to 4 centrads. The Prince phorometer is admirable, however, for testing the insufficiency of some private patients away from the office.

The Meister Phorometer (Fig. 280).—This apparatus, with its folding handle, spirit level and adjustable pair of 15-centrad prisms and adjustable Maddox multiple red rod, is a veritable "Multum in Parvo." The writer takes great pleasure in giving it his cordial endorsement, for with its strong prisms it will do as much and more than the Stevens and Prince phorometers combined.

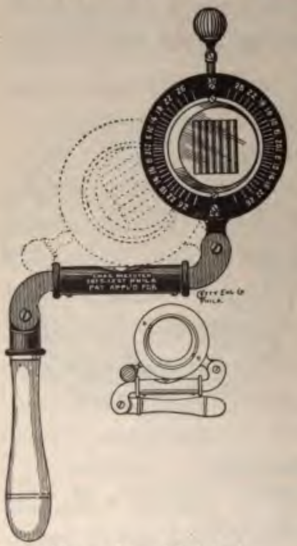


FIG. 280.—Meister's phorometer.

Savage's Cyclophorometer (Fig. 281).—This instrument is used for detecting and measuring cyclophoria—a tendency of the vertical axes of the eyes to lose parallelism with the median plane of the head.

The instrument consists of the equivalent of a two-cell trial-frame with revolving cells mounted so the pupillary distance may be varied by a set screw at the end of the supporting bar. The arm carrying the cells is provided with a leveling attachment and a spirit level.

In examining for cyclophoria a multiple Maddox rod is placed in each of the revolving cells and a 5° prism, base up, behind one of them. The patient sees two horizontal lines of light, which should be parallel and the ends even. The latter *can be regulated* by varying the pupillary distance. If the

lines are not parallel they may be made so by rotating either Maddox rod, the kind (plus and minus) and degree of the error being shown on the scale.

Cyclo-duction, the intrinsic power of each oblique muscle or of both superior or of both inferior obliques may also be measured.

Savage's Monocular Phorometer (Fig. 282).—This instrument is designed for the determination and measurement of insufficiencies of the various ocular muscles, and is based on the principle that the image in one eye throughout every test shall be undisturbed.

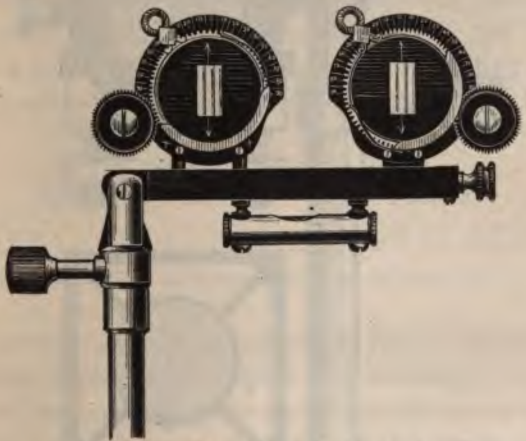


FIG. 281.—Savage's cyclophorometer.

It consists principally of a rotary variable prism correctly marked in degrees and lettered to show the various conditions of muscular imbalance, such as exophoria, esophoria, hyperphoria, etc. On each side of the rotary prism are cells, in one of which, toward the patient's face, is to be placed the displacing prism for causing diplopia. These prisms are carefully mounted in square cells for securing accurate position at either 90° or 180°. The instrument is supplied with a spirit-level and a leveling screw.

The prism is reversible for either eye.

While most of the apparatus and descriptions just mentioned are for testing the muscular conditions at 6 meters, it is necessary to test muscular anomalies at a close range, *i.e.*, at 13 in. (33 cm.), as this is the average reading and working distance with the eyes at close occupations.

Tests for Muscular Imbalance at 33 Centimeters.—Have the patient look at a small black dot with a fine black line 2 or 3

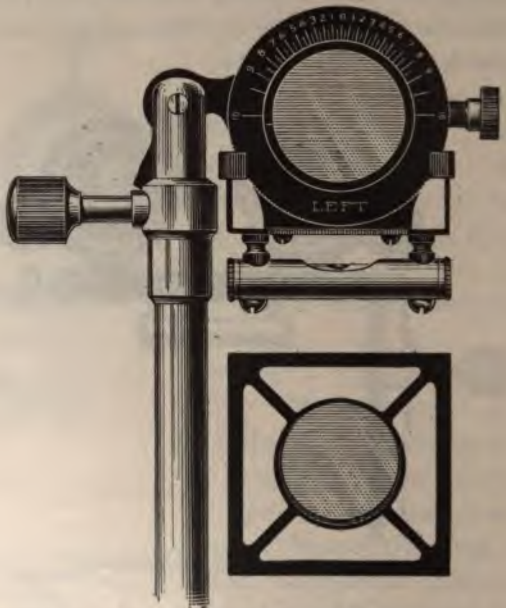


FIG. 282.—Savage's monocular phorometer.

in. long running perpendicularly through it, at a distance of about 13 in. This is known as the line-and-dot test of von Graefe for near testing, and on a larger scale is described in the previous tests at 6 meters. A prism of 7 or 8 centrads is placed, with its base down, in front of the left eye. If the patient sees two dots exactly one above the other on one line there is not supposed to be any lateral insufficiency. If, however, there *are two lines* and two dots and the upper dot and line are on the

left, then there is esophoria for near. The amount of the esophoria is represented by the strength of the prism, placed base outward before the right eye, which will bring the two dots exactly on one line. If the upper dot and line are to the right, then there is exophoria for near, and the amount of the exophoria is represented by the strength of the prism placed base inward over the right eye which will bring the two dots, one above the other, on one line.

Another method for testing lateral insufficiency at the reading distance of 13 in. is to have a card about 6 in. square, and on this card to draw a heavy black line about 4 in. long; this line to be placed exactly horizontal. At the middle of the horizontal line draw a heavy black line, ½ in. long, extending vertically from the horizontal line, this short vertical line to be capped

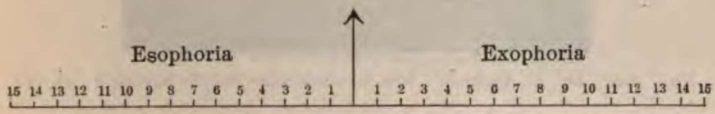


FIG. 283.—Scale for testing lateral insufficiency at 13 in.

with an arrow point. The horizontal line is divided off into equal spaces, each 3⅓ mm. apart and numbered from 1 to 15 each side of the arrow; those to the left of the arrow are marked "esophoria," and those to the right of the arrow are marked "exophoria" (Fig. 283).

To use this method, a prism of 8 centrads is placed base down before the left eye; this doubles the scale vertically; the upper scale belongs to the left eye. The number and the word in the upper scale to which the arrow in the lower scale points is the approximation in centrads of the amount of the esophoria or exophoria. For instance, if the lower arrow points to figure 9 in the upper scale to the right of the upper arrow, that is to the word "exophoria," then there will be approximately 9 centrads of "exophoria" at this distance of 13 in., the distance at which this scale is intended to be used.

To Test for Hyperphoria at 33 Centimeters.—Place a 10-centrad prism base in before the left eye as the right eye fixes

FIG. 284.—Dr. E. Jackson's test for muscular insufficiencies at 33 cm.

the line and dot of von Graefe as in the former test, except that the line is placed horizontally. If there are two dots on the horizontal line, then there is no vertical deviation, but if there are two dots and two lines one above the other, then there is a vertical deviation. If a prism base down before the right eye brings the two lines together, then there is right hyperphoria; if the prism base up before the right eye brings the two lines together, then there is left hyperphoria.

FIG. 285.—Dr. S. L. Ziegler's Greek cross as a near test object.

The large black square and small white millimeter square in its center as suggested by Dr. Jackson makes an excellent test for muscular imbalance at 33 cm. (Fig. 284). The small white square is made to appear double with a 10-centrad prism base down before the left eye.

The small Greek cross (Fig. 285) suggested by Dr. S. L.

Ziegler answers the same purpose as the Jackson squares. Other authorities are partial to a printed word like DIOPTER, for instance; this is made to appear double with a 10-centrad prism base down before the left eye. If the letters appear directly above each other, D over D, I over I, etc., then there is no lateral deviation, etc.

The writer, however, is partial to the Maddox scale shown in Fig. 283. The narrow-lined cross with central dot is also popular and is not without merit (Fig. 286).

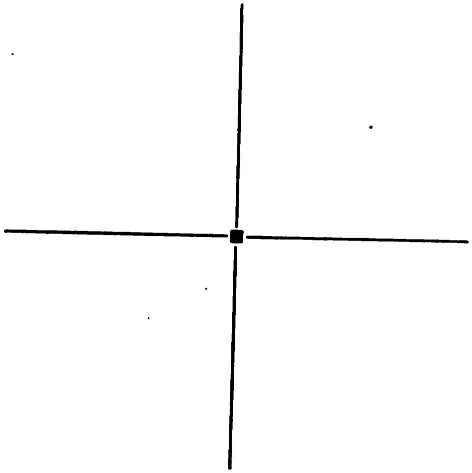


FIG. 286.—Place a 10-centrad prism base down before left eye; if upper cross appears to the left, the condition is esophoria; if to the right, the condition is exophoria. Next place a 10- or 12-centrad base in over left eye; if the left cross is below, then there is left hyperphoria; if above, then there is right hyperphoria.

Stevens' Phorometer.—This is a very convenient apparatus, composed of two 4° prisms placed in a frame 3½ in. from the eyes, which with an attached lever can be rotated so as to test the strength of the vertical and lateral muscles. Indexes and letters at the periphery of the frame record the character and degree of the insufficiency (see Fig. 287).

Treatment of Insufficiencies.—As ametropia is the most common cause of insufficiency, the first consideration must be to

select the proper correcting glasses. After this has been accomplished, if the insufficiency still persists and the patient is not comfortable, then the muscles should receive careful attention, and their condition be studied from every point

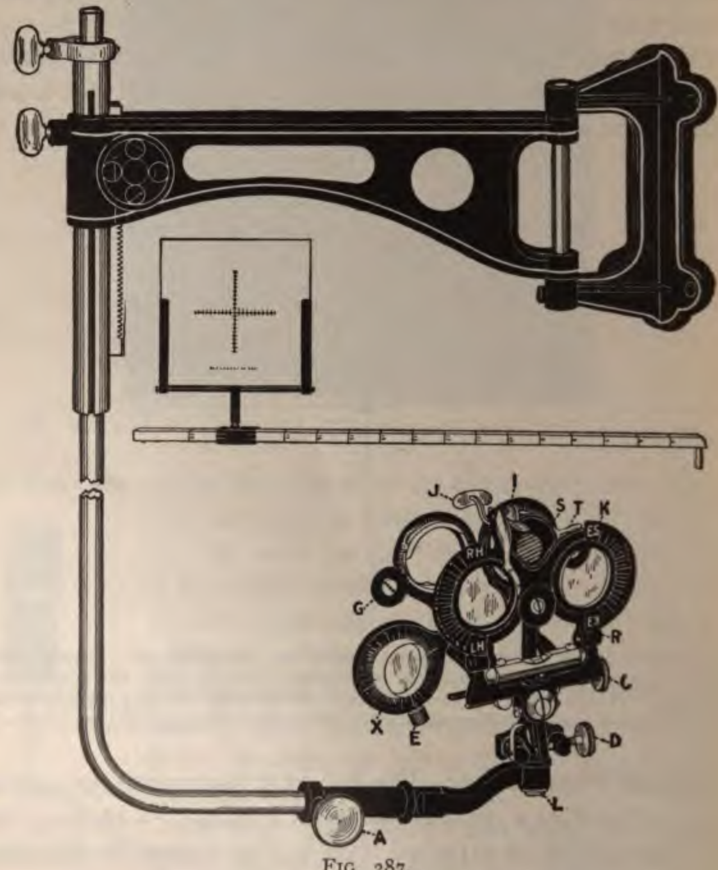


FIG. 287.

of view. The patient's general health should be looked after, and if at all defective, must have remedies prescribed for its improvement. In some instances the patient may have to give up any close application of the eyes for a time and pursue an out-

door life. Operative interference (tenotomy) must not be entertained until all known means for the relief of the muscular asthenopia have been exhausted.

The prescribing of prisms, as a fixed rule, for permanent use, which correct insufficiency except in vertical errors, or for old people (see Exophoria), is often a serious mistake, as in most instances they often do more harm than good by increasing the difficulty. Internally, sedatives will frequently give great satisfaction and permanent relief. The writer is partial to the use of bromids with small doses of the iodid of potash three or four times a day. The *modus operandi* is not clear. The only guide that can be suggested is to use sedative treatment and rest of the eyes whenever there is a congestion of the choroid and retina and when the ophthalmoscope shows the nerve edges hazy, the retina woolly, etc. In another class of patients the internal use of nux vomica is the treatment *par excellence*, and it acts best in those cases in which the nerve edges and the eye-ground in general appear clear and free from irritation. To use nux vomica, it must be given in the form of the tincture and increased, one drop at each dose, until the patient becomes quite tolerant to it, taking as high as 30, 40, or even 50 drops three times a day, and then the dose is gradually diminished. Nux vomica does not seem to benefit cases in which the bromids are indicated as above, and *vice versa* (De Schweinitz).

Remarks.—Patients with weak adducting power (see Fig. 255) cannot all be treated alike with the expectation of equally good results in all cases, and the writer from personal experience divides his cases of exophoria into two classes:

Class 1 embraces those who are not presbyopic and can use one pair of glasses for all purposes of distant and near vision.

Class 2 embraces those who are presbyopic or those who require two corrections, one for distant vision and another for near work (or bifocals).

Treatment of Insufficiency of the Internal Recti.—Because the tests for heterophoria at 6 meters show an ability on the part of the patient to maintain equilibrium, it must not be supposed that there may not be an insufficiency. The normal ratio of adduction to abduction should be taken into consideration in every instance before coming to any such conclusion.

After the proper correcting glasses have been prescribed and the patient's general health looked after, attention, if necessary, should be directed to strengthening the weak muscles, and to do this they must be given a certain amount of systematic exercise, known as ocular gymnastics. That success shall result from ocular gymnastics means perseverance on the part of the patient and the exercises systematically executed. There are two methods of procedure in cases of exophoria:

1. Have the patient "fix" the point of a pencil, or the end of his finger held at arm's length, and *slowly* draw it toward the bridge of the nose. If diplopia results while doing this, the exercise should cease, and be repeated from the original distance. This is a very convenient exercise and should be practised for five or ten minutes after meals; never before a meal, as some patients become nauseated if the stomach is empty. This mode of exercise to develop adduction is much better in every way than by prism exercises; in fact, the writer has long since abandoned exercises with prisms for cases of exophoria.

2. **Prism Exercises.**—The patient is placed, standing, about a foot or two from a point of steady light, on a level or slightly below the level of the eyes, and told to look at it, and at nothing else. In this position a pair of weak prisms (2^{Δ} or 3^{Δ}), bases out, in a trial-frame are placed in front of his eyes.

Then he is told to walk slowly backward across the room, as he keeps his eyes fixed on the point of light. Should diplopia develop at any distance short of 20 ft., then he is to raise the prisms, go back to his original position, and start over again. Repeating this a number of times in the surgeon's office, it will *be found, in* most instances, that at the first practice a pair of

5 Δ or 10 Δ can be overcome at a distance of 20 ft. When the distance of 20 ft. from the light is reached without developing diplopia, the patient is instructed to slowly count 20 or 30 (keeping the light single during this time), then raise the prisms (gazing at the light), and to slowly count 20 or 30 again. This exercise is repeated three times a day after meals and a number of times at each practice. A prescription is given for such a pair of square prisms with a convenient frame to wear over the patient's glasses. These exercises should, as a rule, be conducted with the patient wearing his correction. Instead of the prism-frame, the patient may hold the square prisms with his hands; but these are tiresome to hold, and for general use the prism-frame, if not too heavy, is preferable. After a few days' practice at home, the patient returns, and stronger prisms which will permit the patient to maintain single vision are ordered. This practice with stronger and stronger prisms is repeated until the patient is able to overcome prisms greatly in excess of the normal ratio of adduction to abduction. It is often well to develop the power of the internal recti to three or four times the strength of the external recti, for the reason that when the exercises are stopped, some of the strength of adduction will rapidly disappear.

It has been incidentally mentioned that prisms should not be prescribed in combination with the ametropic correction for the treatment of insufficiency, and yet there is an occasional exception to this statement in cases which must have prompt, though temporary, relief. When ordering prisms for such a case, it is best to prescribe them in the form of hook fronts, so that they may be thrown aside at any time. What has just been stated in regard to treatment applies particularly to patients in Class 1.

Treatment of Class 2.—Patients in this class, as just stated, are usually presbyopic and therefore require two corrections (see Presbyopia). Presbyopes with exophoria have reached a stage in life when it is difficult or almost impossible to put new

life into old structures, and it does seem as if the extra-ocular muscles like the ciliary muscle were no exception to this statement; and this fact becomes more and more evident as the patient passes beyond 50 years of age. Developing adducting power by practising fixation at 33 cm. (page 272) may accomplish a good deal of good in some young presbyopes, but taking a presbyope of 50 or 55 or 60 years of age and trying to develop adduction with fixation or prism exercises is, in almost every instance and with few exceptions, a waste of time and patience. These presbyopes do not take kindly to such treatment and, in the writer's experience, patients so treated soon seek assistance elsewhere. In hyperphoria the full prismatic correction (except in cases of presbyopia) is seldom ordered—only about two-thirds of it, and this is divided between the two eyes—base down before one, and base up before the other.

Testing the muscular condition at 33 cm. with the presbyopic near correction before the patient's eyes, there should be about 10° of exophoria normally at this distance, but if there happens to be 12°, 14°, or 16° of exophoria, then the presbyope is uncomfortable and complains correspondingly when using the eyes at near work for any length of time. The treatment of exophoria at the working distance in presbyopes is to add or prescribe prisms bases in to be made in the near correction. The amount of prism to be so ordered is usually divided between the two eyes. As 10° of exophoria is normal for this distance of 33 cm. as just mentioned, then the amount of prism prescribed will be practically two-thirds of the amount shown in excess of the normal 10°. For example, the patient at 50 years of age selects for each eye +1 sphere periscopic and has a vision of $\frac{VI}{VI}$ in each eye with this correction and does not reveal any insufficiency at 6 meters, but when +2 sphere is added for near, then at 33 cm. there is found to be 16° of exophoria. After using the glasses for a few days at home the patient returns complaining that at close work the eyes pain, *feel sore to* the touch, has occipital headache, smarting of the

lids, and blurred vision. The exophoria in this instance at 33 cm. is 6° in excess of the normal amount. Ordering two-thirds of this amount (4°) divided between the two eyes, the patient will receive one of the following prescriptions:

℞. O. D. +1.00 S. D. Periscopic
O. S. +1.00 S. D. Periscopic
SIG.—For distance.

Also

℞. O. D. +3.00 S. D. ⌔. 2 P. D. base in.
O. S. +3.00 S. D ⌔. 2 P. D. base in.
SIG.—For near only.

Or

℞. O. D. +3.00 S. D. ⌔ decentered in 7 mm.
O. S. +3.00 S. D. ⌔ decentered in 7 mm.
SIG.—For near only.

Or

℞. O. D. +1.00 S. D. Periscopic
O. S. +1.00 S. D. Periscopic
SIG.—For distance.

Cement on to lower part of the above for near.

O. D. +2.00 S. D. ⌔ 2 P. D. base in.
O. S. +2.00 S. D. ⌔ 2 P. D. base in.
SIG.—Make bifocals.

If another patient had 2° or 3° of exophoria at 6 meters with the same correction (1.00 S. D. Periscopic in each eye) it would not be wise to give the distance correction, but to allow him to use his relative hyperopia and at the same time to prescribe the fixation exercises if he becomes uncomfortable in the use of his eyes at a distance. Another very good treatment in cases of exophoria to encourage convergence is to prescribe a weak solution of eserin or pilocarpin, quarter of a grain to the ounce, and to use one drop in each eye each night and morning.

Treatment of Insufficiency of the External Recti (Esophoria) (Fig. 254).—As esophoria is a tendency of the visual axes to

deviate inward, it will be found that patients with this form of insufficiency, when of 2° or 3° or 4°, suffer very little, as a rule, when using the eyes at near work; their chief discomfort arises from using the eyes for distant vision. The "shopping headache," the "opera headache," the "train headache," may be due to this form of insufficiency, as well as exophoria, but it is not so apt to cause discomfort if the ametropic correction is worn constantly. In other words, if an esophoric does not wear his distance correction and accommodates at the same time that he endeavors to maintain equipoise (relative hyperopia), he may at times suffer severely. If the symptoms of muscular asthenopia persist after prescribing the ametropic correction, then prisms, bases out, may be prescribed as hook fronts to be worn over the constant correction when using the eyes for distance. Prism exercises (prisms, bases in) for esophoria do not always benefit, and are occasionally a waste of time; yet they should be tried thoroughly if the case appears to demand it. When the esophoria amounts to 6° or 8° or 10°, then the patient will usually have marked symptoms, such as ocular pains, occipital headaches, pains running into the neck and sometimes into the shoulders. They do not have any comfort when reading, or writing, and in fact often have to abandon any prolonged use of the eyes at any near work.

When the patient has several degrees of esophoria for distance he must use his distance correction which usually corrects any former discomfort in the use of his eyes for distance; but he may continue to have discomfort at any near work, such discomfort as ocular pains, occipital headache, pains running into the neck and sometimes felt between the shoulders. Such patients do not have any comfort from their eyes when reading or writing or at any close work which requires the eyes to move instead of remaining fixed. For instance, a sewing woman will come with the story that she can sew with comfort with her glasses on, but that she cannot read with comfort and she cannot understand why. A stenographer who runs the typewriter

during the day suffers from the symptoms just described, yet she can sit and sew in the evening and not get a headache. The trouble lies in weak abducting power or excessive adducting power. The question of treatment in such cases is not to weaken adduction but to strengthen abduction. The writer's method of treatment, which he believes to be original, is to practise abduction or turning outward of each eye separately, that is to turn each eye outward while its fellow is covered. This is illustrated in Fig. 288. The patient is told to fix his head in one position and not to turn it while practising as

FIG. 288.

follows: to cover the eye with a card as shown and in such manner that the covered eye cannot see what the other eye is doing; then, holding the index-finger point on a level with the eye, the finger is gradually made to describe a quarter circle to the same side as the eye being exercised; the eye fixes the point of the finger to the limit of external rotation. First one eye and then the other eye is exercised in this way for five or ten minutes after each meal. Marked im-

provement will follow this treatment in a very few days, and the writer can testify to some most remarkable results by this very simple method of strengthening abduction. Occasionally this practice alone will not suffice and the patient will also have to use prism exercises (bases in).

If this class of patients has orthophoria or esophoria at 33 cm. the writer prescribes either bifocals or a near correction by adding +1.00. or +2.00.

Treatment of Insufficiency of the Superior and Inferior Recti.—Having prescribed the ametropic correction, an attempt should be made to strengthen the weak muscles by prism exercises—prism base down before one eye, and base up before the other eye. While this does not often give satisfactory results, yet it should be tried in each instance. If prism exercises do not correct the difficulty, then prisms which overcome most of the insufficiency should be prescribed for constant use. Failing in this second attempt with prisms or with a *full* prismatic correction, then tenotomy of the overacting muscle or muscles must have consideration.

Tenotomy.—As previously stated, *tenotomy should never be resorted to until every other known means of relief has been tried*, and even then no hard-and-fast rule can be given for *the amount* of the insufficiency in degrees which will prompt such a procedure. Some patients with as much as 2° or 3° of esophoria may never suffer the least annoyance; and yet other patients with the same amount will estimate their sufferings as almost beyond endurance. And the same statement holds good in other forms of insufficiency, especially exophoria. The question of personal equation, the patient's nervous system, hysteric tendencies, etc., must all be considered before undertaking a tenotomy that may result in nothing but discouragement.

If an operation has been deemed best, then it is for the surgeon to decide whether he will divide the tendon of the strong muscle or advance the weak muscle, or both. Whatever opera-

tion or operations are performed, the amount of the deviation should be estimated immediately before, as well as after, the operation. When a simple tenotomy is performed, the eye is usually left open (unbandaged) so that fixation is maintained, and the muscle balance tested frequently to see that, by subsequent contraction, the insufficiency does not return. To avoid such a misfortune it may be necessary to use prism exercises during the healing process. The writer is not an advocate of partial tenotomies. It is an interesting fact, nevertheless, that after a tenotomy, if any annoying insufficiency remains, it can usually (though not always) be successfully relieved by prescribing the necessary correcting prism to be made in the correcting glasses.

Strabismus (*στρεψω*, "to turn aside"); also called heterotropia, "cross-eye" or "squint," or manifest squint. This is a condition of the eyes in which the amount of the squint is so great that it cannot be overcome by muscular effort; and, in fact, inspection shows the manifest condition. Or strabismus may be defined as the condition in which the visual axis of one eye is deviated from the point of fixation. The eye which has the image of the object on its fovea is spoken of as the fixing eye, while the other eye is termed the squinting or deviating eye. The squinting eye does not always have normal visual acuity; and, in fact, correcting lenses will not always produce such a result.

Varieties of Strabismus.—There are three varieties of strabismus, namely: (1) **Esotropia** (internal squint, concomitant, convergent strabismus, monolateral convergent squint); (2) **Exotropia** (external squint, concomitant divergent strabismus, monolateral divergent squint); (3) **Hypertropia** (vertical squint, right or left).

Esotropia, Convergent squint (*con*, "together," and *vergere*, "to incline or approach"); also called internal squint (strabismus convergens), concomitant squint. This is the condition in which the visual axis of one eye is deviated inward, the

other fixing the object; or one eye fixing an object, the visual axis of the other eye crosses that of the fixing eye closer than the object (see Fig. 252). This is the most common form of squint. Generally both eyes have some form of hyperopia, and as a rule, the squinting eye is usually more ametropic. The diplopia as a result of this condition is homonymous.

Exotropia, Divergent squint (*di*, "apart," and *vergere*, "to incline"); also called external squint (strabismus divergens), concomitant squint, (see Fig. 253). This is the condition in which the direction of the visual axis of one eye is directed outward, the other eye fixing the object; or one eye fixing an object, the visual axis of the other eye can cross it only by being projected backward. The diverging eye is usually myopic, but not always.

Varieties of Esotropia, Exotropia and Vertical Strabismus

Monocular (monolateral or one-sided squint) also called constant. The squint is a condition of one eye only and may be either convergent or divergent so that it is spoken of as right or left monocular convergent or divergent squint as the case may be. Occasionally the word concomitant is associated, for instance, right or left monocular comcomitant convergent or divergent squint. In concomitant squint the deviation persists no matter in what position the eyes are turned. The power of rotation of the squinting eye is not impaired, although it lags behind its fellow.

Alternating Squint.—This is the condition in which the right eye fixes and the left eye squints, or the left eye fixes and the right eye squints (convergent or divergent), or one eye fixes and the other turns up or down. The vision in each eye in cases of alternating squint is usually the same or nearly so.

Periodic squint, also called intermittent, temporary, transient. This may be either convergent or divergent, hence it is *spoken of* as periodic (intermittent, temporary, transient) con-

vergent or divergent squint as the case may be. This is the condition in which the visual axis of one eye occasionally deviates. It is frequently the very first indication of a beginning constant (monocular or monolateral) convergent or divergent squint.

Paralytic Squint.—This is the opposite of the concomitant squint as the paralyzed muscle restricts the movement of the eye in a certain direction, the opposing muscle pulling the eye in the direction opposite to the paralyzed muscle. Hence we may have a right or left monocular divergent squint due to a palsy of the right or left internal rectus as the case may be or we may have a right or left monocular convergent squint due to a palsy of the external rectus of the right or left eye as the case may be.

Causes of Squint.—These are many and various. The chief causes, however, are: (1) ametropia, which may produce a change in the normal relationship between accommodation and convergence; (2) anatomic anomalies; (3) mechanic anomalies; (4) amblyopia and (5) palsy.

1. **Ametropia** produces a change in the normal relationship between accommodation and convergence. While it is possible for accommodation to take place without convergence, or convergence without accommodation, yet there is an affinity between the two processes which, if materially interfered with, will produce diplopia and eventually squint. In speaking of relative hyperopia, it was shown that the accommodative effort was accompanied by contraction of the internal recti muscles (convergence); so that in hyperopia of, say, 4 diopters, accommodating for infinity, convergence would be stimulated to a proportionate degree at the same time; and if accommodating for a near point, the hyperope must accommodate and converge just that much in excess of what standard eyes would do (see pages 107, 124). The result is that a person with a hyperopia of any considerable amount frequently squints inward in the effort to maintain binocular vision. If, now, one

eye is more hyperopic than the other, the difficulty of adjusting convergence to accommodation is increased. Say that the right eye has 3 diopters and the left 4 diopters of hyperopia; then the two eyes exert 6 diopters to fix at 13 in.; the left eye still has 1 diopter of its hyperopia remaining, and with the result that the retinal image of that eye is not clear, and accommodation is still further taxed, stimulating at the same time the internal rectus, so that the left eye deviates inward and ultimately remains convergent. This act of convergence explains the presence of convergent squint in hyperopia, and also shows why the squinting eye usually has the higher refractive error. It must not be supposed that all hyperopic eyes have a squint, as some of these can accommodate without converging in a proportionate degree, and this is especially so when the amount of the hyperopia is about the same in both eyes.

Myopic eyes, in contradistinction to hyperopic eyes, cannot accommodate beyond their far points, but must converge. If the myopia is 8 diopters, then these eyes would have to converge 8 meter angles to fix an object at that distance (5 in.) without any accommodative effort. It must also be borne in mind that myopic eyes are long eyes, and that to converge 8 meter angles means a great effort on the part of the internal recti muscles, and this force cannot be continued for any length of time without discomfort; the result is, convergence is relaxed, and, one eye remaining fixed, the other is turned outward. This is much more likely to happen if one eye is more myopic than the other. This explains the presence of divergent squint in cases of myopia. But it must not be supposed that all myopic eyes necessarily have squint, as some of them have roomy orbits, strong internal recti muscles, and a short interpupillary distance.

2. Anatomic Anomalies.—This applies especially to the breadth of the face (skull) and the size of the eye and orbit. The broad face, which naturally gives a long interpupillary *distance, pre*disposes to greater convergence than the narrow

face. The long, myopic eye would not have the freedom of movement that the short eye possesses in the same sized orbit.

3. **Mechanic Anomalies.**—This refers especially to the length and strength of the extra-ocular muscles. Short and strong internal recti would predispose to convergent squint, whereas strong external recti would develop divergent squint.

4. **Amblyopia.**—Statistics show that from 30 to 70 per cent. of all squinting eyes are amblyopic. The cause of the amblyopia may be that the eye was born defective in its seeing quality; *i.e.*, the cones at the fovea, the optic nerve, or the visual centers in the brain may be at fault. Or if born perfect and having its visual axis deviated by one of the many causes above mentioned, it may become amblyopic from want of development of the fusion center. This consideration of cause and effect is most important from a prognostic point of view.

Among other causes of squint must be mentioned opacities of the media, as nebula of the cornea, or any want of transparency in the cornea at or near the visual axis, or polar or nuclear cataract. Temporary or intermittent squint may result from vitreous opacities or from the remnant of a hyaloid artery passing in front of the fovea. Parents occasionally delude themselves with the idea that the child's squint is the result of whooping-cough, measles, teething, sucking the thumb, or imitating a companion, etc., and are slow to believe that there can be any refractive error, forgetting that the supposed causes they mention may be but coincidences.

To Estimate the Amount of the Strabismus or Squint.—This is not always easy at the beginning of the examination, for the reason that the squinting eye has long since learned to ignore the false object; and if the angle of the strabismus is large, the surgeon will have to reduce it in part with a prism, so that the patient can see the false object; and if this is a point of light, a piece of dark red glass will have to be placed in front of the fixing eye. The strength of the prism required to bring the

two lights together will be the prismatic estimate of the deviation. Or the amount of the squint may be roughly determined with the strabismometer (see Fig. 289). This is a piece of bone or ivory hollowed on one side so as to fit the curve of the eyeball. Its edge is graduated in millimeters. This device is held gently against the lower lid of the squinting eye, so that the zero (o) mark corresponds to the center of the pupil as the eye fixes a distant object, the fellow-eye being under cover. When the cover is removed, the squinting eye again deviates, and the amount of the deviation is again noted by the position of the center of the pupil of the squinting eye over the millimeter line on the instrument. Each millimeter of deviation is supposed to represent 5° of deviation. This device is not reliable, and is not in common use.

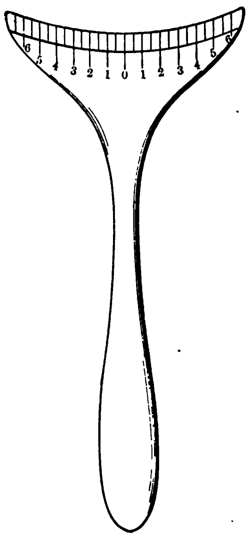


FIG. 289.

A more reliable estimate is obtained by measuring the deviation on the arc of the perimeter (see Fig. 290). To do this, the patient is seated with the squinting eye opposite to the fixation point (R) and instructed to look with the fixing eye at a distant object (R) across the room, so that the object, the fixation point, and the squinting eye (R) are in line; this line represents the direction which the eye would take normally. The observer, taking a lighted candle, places it at the fixation point and gradually moves it outward along the inner surface of the arc until his own eye, *directly back of the flame*, sees an image of the flame at the center of the pupil of the squinting eye. The degree mark on the arc from which the flame was pictured represents the amount of the deviation or angle of the strabismus; this angle being formed by the visual axis with the direction of the normal *visual line*. The degree mark on the arc is in front of the optic

axis and not the visual axis, but for purposes of approximation they are considered as the same.

Treatment of Strabismus.—As ametropia is the chief factor in the cause of squint, this cause must be promptly removed

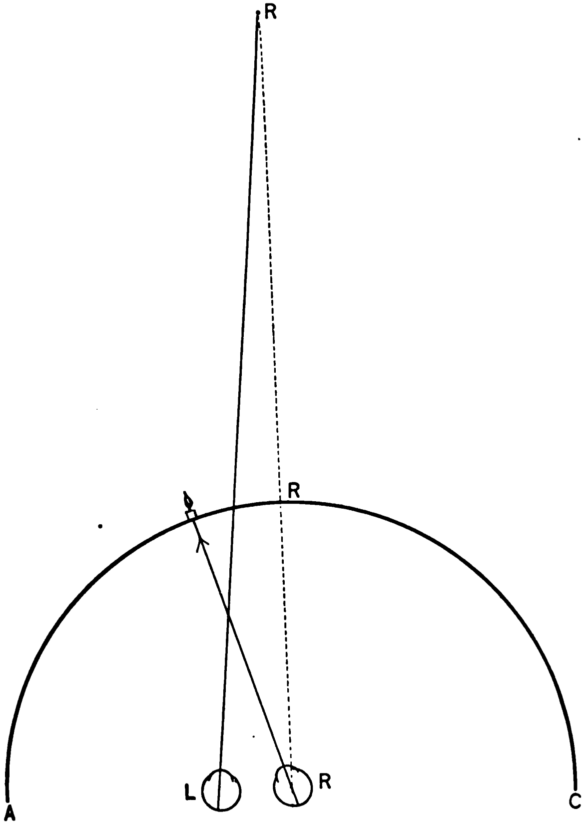


FIG. 290.

by the use of correcting glasses. The correction of the ametropia means four essentials:

1. **In young subjects** the eyes must be put at rest, and kept at rest for **two or three** weeks with a reliable cycloplegic and

dark glasses. Preference is given to atropin in each instance, the writer considering it folly to use homatropin in such cases.

2. During the use of the cycloplegic, the lenses which correct the ametropia are selected with care and the greatest precision, by every known means to this end; and just here is the place of all places to use the retinoscope, as most cases of strabismus appear in children, and, too, the squinting eye often being amblyopic, cannot assist in the selection of the glass.

3. The correcting glasses are ordered in the form of spectacles, and are to be worn from the time of rising until going to bed. The strength of the glasses should be as near the full correction as it is possible to give (see page 372).

4. The "drops" are continued for a day or two after the glasses have been obtained, and in this way, while the drops are still in the eyes, and as their effect slowly wears away, the eyes gradually become accustomed to the new or natural order of accommodation and convergence. After the cycloplegic has entirely disappeared, the patient should be carefully restricted not to use the eyes for near-work for several days or weeks.

As hyperopia and astigmatism in combination are generally congenital conditions, it therefore follows that convergent squint appears quite early in life, as soon as the child begins to concentrate its vision on near objects. The squint, at first periodic or intermittent, finally becomes constant. Such eyes should be refracted at once, and before amblyopia can be established. It is interesting to note that the eyes in many young children (before the seventh year of age) begin to fix or lose their squint as soon as the cycloplegic takes effect. The prognosis is favorable for good vision with glasses when this occurs. It will also be observed in other subjects that while the drops are in the eyes and glasses worn constantly, the squint disappears entirely; but as soon as the cycloplegic passes away and near vision is attempted, the squint returns, and vision falls back in the squinting eye to almost the same point that it had before the cycloplegic was employed. This occurs in cases in which the am-

blyopia is becoming established, or where there is a strong muscle deviating the eye. If the squint is due to amblyopia exanopsia, then the vision may be improved in either one of two ways. One way is to use drops in the fixing eye, and thus compel the squinting eye to do the seeing; or the other way is to cover the fixing eye with a blank over the glass (see Fig. 291), and have the patient practise in this way for one or two hours each day, using the squinting eye alone; or another way is to tie a dark patch over the good eye (under the glasses) when the patient is at the table at meal time, usually with both hands occupied with knife and fork

FIG. 291.

Worth's Amblyoscope or "Fusion Tubes."—To cultivate or develop binocular vision Worth has given us an instrument which he calls an amblyoscope (see Fig. 292). This instrument is in two halves joined by a hinge. Each half consists of a short tube joined to a longer one at an angle of 120°; at the junction of the tubes is an oval mirror. A translucent glass object slide is placed at the distal end of each tube. At the hinged ends are lenses whose focal length equals the distance of the reflected image of the object slide; in front of these lenses are grooves into which additional lenses of the trial-case may be placed to correct the refractive error of the patient. The two halves of the instrument are united by an arc, having a long slot at one end an adjusting screw at the other. The object slides can be brought together to suit a convergence of 60°. When the adjusting screw is used an additional movement of 10° is obtained.

At the far end of each tube there is also a square slot into each of which may be placed half a pictured object; for instance, a

picture of the right side of a man, showing his arm and leg extended, may be placed in the left tube, and in the right tube is placed a picture of the same size, of the left side of the man with his leg and arm similarly extended. When the patient looks into the tubes, the surgeon (or the patient) may adjust the tubes until the two half pictures unite and form one complete picture. Or the picture in one tube may be a picture frame, and in the other tube is a picture of an animal or an object, the idea being to have the patient so fuse the two pictures that the object is placed in the frame. There are many different pictures accompanying the instrument so as to give variety to the daily exercises and thus maintain the patient's interest. This instrument is certainly a valuable one and in many instances accomplishes its purpose.

FIG. 292.—Worth's amblyoscope. (Reduced size.)

Cases that are cured by correcting the ametropia must wear their glasses constantly. Glasses in such cases can seldom be abandoned. In young children the squint returns almost at the instant the glasses are removed. The earliest age at which glasses can be prescribed is three years or thereabouts, as it would be unreasonable in *most* cases to expect a child to appreciate the glasses as anything but a toy before this age.

The younger the patient when glasses are prescribed, the more favorable the prognosis and less likelihood of a tenotomy ever being necessary. The older the patient when glasses are ordered, the less the likelihood that glasses will cure the squint and the greater probability of a tenotomy being necessary. This is explained from the fact that the squint having persisted for a long time, the muscle which held the eye in the deviated *position* has grown strong and the opposing muscle weak.

Vertical squint is seldom cured by correcting glasses alone. Prisms may occasionally be substituted for an operation.

Monocular and alternating squint are greatly relieved by the correction of the ametropia, and may or may not be cured with glasses alone.

Periodic or intermittent squint, if due to permanent opacities in the media, cannot, as a rule, be cured by any form of treatment.

Cases of concomitant squint are generally amenable to operative treatment, whereas cases of paralytic squint are not.

It may be stated as a good rule to follow that *no case should ever be operated upon until the glasses which correct the ametropia have been worn constantly for several weeks after all apparent improvement has ceased.* If cases for operation can be selected, the best age is about puberty, when the muscles have reached a fair state of development. If the squint is due to an anatomically short muscle, then there need not be any great delay in operating after glasses have been ordered.

Several weeks after a tenotomy has been performed, the eyes should again be carefully refracted, as it is a well-established fact that tenotomy often relieves a tension that will materially change the radius of corneal curvature; and hence the amount of the astigmatism and the cylinder axis will be altered.

Tenotomy.—For convergent squint, if of moderate degree, division of the tendon of the internus of the converging eye may be sufficient; but if the squint is considerable, the tendons of both interni may have to be divided. Occasionally, it is necessary to divide the internus and advance the externus.

For divergent squint, if of moderate degree, division of the tendon of the externus of the diverging eye may be sufficient; but if the squint is considerable, the tendons of both externi may have to be divided. Occasionally, it is necessary to divide the externus and advance the internus.

For vertical squint, tenotomy of the stronger superior or stronger inferior rectus, or both, may be necessary.

It is good practice in every instance, before "rushing" into an operation for squint, to take the field of vision and search carefully for a central scotoma, which, if present, should put the surgeon on his guard against operative interference with the hope of obtaining any result other than cosmetic; and even then there is grave danger that the case will soon lapse into the former state of deviation, or possibly deviate in the opposite direction.

Ocular Palsies

While a detailed description of the various ocular palsies and their diagnosis is not a subject matter for a work of this character, yet the writer feels that a brief description is in order to assist the reader in making a differential diagnosis between ordinary squint and that produced by a palsy of an ocular muscle. A proper understanding of what each muscle will do normally and also its nerve supply appears equally necessary.

The ciliary muscle is the muscle of accommodation. The sphincter of the iris controls the size of the pupil. The internal rectus turns the eye inward, the external turns the eye outward, the superior rectus turns the eye upward, the inferior rectus turns the eye downward, the superior oblique turns the eye downward and inward; the inferior oblique turns the eye upward and outward. The levator or elevator of the lid, lifts the lid upward. Branches of the third nerve innervate the ciliary, the sphincter of the iris, the internal rectus, the superior rectus, the inferior rectus, the inferior oblique and the levator. The external rectus is innervated by the sixth and the superior oblique by the fourth nerve.

In making the test for palsies the patient should be seated if possible facing a 2-cm. round and steady light at a distance of 20 ft. on a horizontal line with the normal level of his eyes, never above this level. The phorometer or trial-frame should be carefully adjusted and the patient instructed to hold his *head perfectly* still and not to direct his eyes away from the

light unless told to do so. One eye, usually the left one, is to be covered with a red glass so that its image may be definitely located.

Lateral Diplopia.—Double vision on the horizontal meridian. This means a palsy of the external or internal rectus of either eye. Homonymous lateral diplopia means a palsy of an external rectus.

Crossed or **heteronymous lateral diplopia** means a palsy of an internal rectus.

Palsy of the Right Externus.—Homonymous diplopia, which increases when the vision is directed to the right and diminishes when the vision is directed to the left.

Palsy of the Left External.—Homonymous diplopia which increases when the vision is directed to the left and diminishes when the vision is directed to the right.

Palsy of the Right Internus.—Crossed or heteronymous diplopia which increases when the vision is directed to the left and diminishes when the vision is directed to the right.

Palsy of the Left Internus.—Crossed or heteronymous diplopia which increases when the vision is directed to the right and diminishes when the vision is directed to the left.

Vertical Diplopia.—If the diplopia increases when the vision is directed upward, there is a palsy of an elevator, either the superior rectus or inferior oblique. If the diplopia increases in looking downward there is a palsy of a depressor, either the inferior rectus or superior oblique.

Palsy of Right Superior Rectus.—Vertical diplopia increasing when the vision is directed upward and to the right, image of right eye being above.

Palsy of Left Superior Rectus.—Vertical diplopia increasing when the vision is directed up and to the left, image of left eye being above.

Palsy of Right Inferior Rectus.—Vertical diplopia which increases when the vision is directed down and to the right, image of right eye below.

Palsy of Left Inferior Rectus.—Vertical diplopia which increases when the vision is directed down and to the left, image of left eye below.

Palsy of Right Superior Oblique.—Diplopia which increases when the vision is directed down and to the left, image of right eye below.

Palsy of Left Superior Oblique.—Diplopia which increases when the vision is directed down and to the right, image of left eye below.

Palsy of Right Inferior Oblique.—Diplopia which increases when the vision is directed up and to the left, image of right eye being above.

Palsy of the Left Inferior Oblique.—Diplopia which increases when the vision is directed up and to the right, image of the left eye being above.

An excellent way to make a quick diagnosis of a paralytic cyclotropia, is to place a Maddox Rod before each eye with the streak of light at 90° so that each eye would normally see a vertical streak of light when looking at a point of light at 20 ft. The eye with the palsy of one of the obliques would see a streak of light tilted markedly with the upper extremity *toward* the true image in palsy of the superior oblique and the upper extremity of the false image tilted markedly *away* from the true light in palsy of the inferior oblique.

CHAPTER XVII

CYCLOPLEGICS.—CYCLOPLEGIA.—ASTHENOPIA.—EXAMINATION OF THE EYES

A cycloplegic (from the Greek, κύκλος, "a circle,"—*i.e.*, the ciliary ring,—and πληγή, "a stroke") is a drug which will *temporarily* quiet or put at rest the ciliary muscle.

A mydriatic (from the Greek, μυδρίασις, "enlargement of the pupil") is a drug which will *temporarily* dilate the pupil.

Atropin will dilate the pupil and also cause a temporary rest of action of the ciliary muscle. Cocain will cause a dilatation of the pupil, but will not quiet the action of the ciliary muscle. A cycloplegic is also a mydriatic, but a mydriatic is not necessarily a cycloplegic.

The Uses of a Cycloplegic.—(1) To temporarily suspend the action of the ciliary muscle, or to put the eye in such a state of rest that all accommodative effort is for a time suspended while the static refraction is being estimated. (2) The retina and choroid are given an opportunity to recover from irritation and congestion incident to eye-strain ("eye-stretching"). There are many different cycloplegics employed for estimating the static refraction, and each has particular qualifications for individual cases. Cycloplegics may be classed as of three kinds: (1) those the effect of which passes away slowly; (2) those the effect of which passes away moderately fast; and (3) those the effect of which is very brief.

The first effect of a cycloplegic is its mydriatic quality, after which the accommodative effort is temporarily suspended. The quieting effect is not permanent. The following table, from Jackson, shows the length of time the quieting effect persists and the time it takes for the ciliary muscle to fully recover:

Atropin, effect begins to diminish in 4 days; complete recovery, 15 days.
Daturin, effect begins to diminish in 3 days; complete recovery, 10 days.
Hyoscyamin, effect begins to diminish in 3 days; complete recovery, 8 days.
Duboisin, effect begins to diminish in 2 days; complete recovery, 8 days.
Scopolamin, effects begins to diminish in 12 hours; complete recovery, 6 days.
Homatropin, effect begins to diminish in 12 hours; complete recovery, 2 days.

If a solution of one of the above-mentioned cycloplegics is instilled into the conjunctival sac of a healthy eye, it will be carried by the blood- and lymph-vessels at the sclerocorneal junction into the ciliary muscle and iris, where it acts directly upon the nerves and ganglia of these structures, and the aqueous humor also receives some portion of the drug. If cautiously used, the action will be limited to one eye, showing that the drug does not pass through the cardiac circulation; otherwise, the pupil and ciliary muscle of the fellow eye would be similarly affected.

Occasionally a conjunctiva is sensitive to any of these drugs, and may develop an inflammation so severe in individual instances as to resemble ivy poisoning of the lids. Duboisin especially, and hyoscyamin, by absorption (if carelessly used), may produced hallucinations and even a temporary loss of coordination.

Any cycloplegic, in fact, when carelessly used, may produce very unpleasant symptoms, such as dizziness, dry throat, flushed face and body (mistaken for scarlatina), rapid pulse, a slight rise of temperature, and delirium. To avoid such an annoyance, which is apt to reflect discredit upon the physician and upon the profession in general, the patient should always be given definite instructions how to use the drug in each instance. Stopping the use of the drug and applying cold compresses will relieve the conjunctivitis, and if constitutional symptoms manifest themselves a dose of paregoric, cooling, drinks, a darkened room, and stopping the use of the drug will soon restore the patient. No fatalities to life have ever been reported when cycloplegics have been used in the eyes.

FORM OF PRESCRIPTION

Name, MR. BROWN.

℞. Atropin. sulphatis.. gr. j
Aquæ dest.. f ℨij.

M. Ft. sol. *Label*, poison drops!!

SIG.—One drop in each eye three times a day, as directed.

℞. Dropper. DR.——

Date, Tuesday, March 14, 1899.

The reason for labeling this prescription "poison drops" is not to frighten the patient, but to caution him against leaving the medicine where children may get hold of it, and at the same time to let him understand that it is to be used and handled with care.

Mr. Brown is told to have one drop put in each eye three times a day, after meals, and to report at the office on Thursday (the prescription is given on Tuesday in this case). The reason for using the drug for this length of time is to insure complete ciliary muscle repose, and also to give the eyes a physiologic rest. In having these "drops" put in the eyes, the patient should tip his head backward and turn his eyes downward, and as the upper lid is drawn up, one drop (from the dropper) is *placed* (not dropped) on the sclera at the upper and outer part. After the drops are placed in the eyes, as far away from the puncta lachrymalia as possible, the patient holds the canaliculi closed by gently pressing with the ends of the index-fingers on the sides of the nose at the inner canthi for a minute or two. If more than one drop enters the eye, it will run over on to the cheek, and should be wiped off. With children, these instructions are not so easy of execution, and the writer has seen a few such clinical subjects flushed and delirious from gross carelessness on the part of parents in dropping the medicine into the inner canthi, where it soon passed into the nose, or else the drug is allowed to flow over the cheek and into the child's open mouth. Ordinarily, there need *never* be any discomfort from the use of these drugs beyond a slight dryness of the fauces.

Caution.—Cycloplegics should never be used when there is the least suspicion of glaucoma in one or both eyes. Cyclo-

plegics should not be used in the eyes of nursing women; such patients are peculiarly susceptible to the action of these drugs, and the mammary secretion may thereby be diminished in amount. After the age of 45 or 50 years, or in the condition known as presbyopia, it is seldom necessary to use a cycloplegic. If a cycloplegic is necessary in presbyopia, one of the weaker drugs is generally employed.

In the selection of a cycloplegic the surgeon must be guided by the patient's occupation, age, the character of the eyes, and the refraction. From the foregoing table it will be seen that atropin and daturin are slow in passing from the eye, making their employment on this account very objectionable in many instances. The accommodation returns sooner after the use of hyoscyamin and duboisin than from atropin, but not so promptly as from scopolamin and homatropin. The effect of the latter is very brief. A patient who might lose his business position if he remained away from work for more than a week could not afford to have atropin or daturin used in his eyes, whereas a school child might accept atropin as a luxury. The man of business, the cashier in a bank, the storekeeper, and others must, in many instances, have their eyes refracted in at least two days; and this latter time means, of course, the use of homatropin. The nearer the age to 40 years, the less need for one of the stronger cycloplegics, as the power of accommodation has markedly diminished at this period of life. After 35 years homatropin can, as a rule, be relied upon as a cycloplegic.

In hyperopic eyes of young subjects it is useless to employ homatropin, as the active ciliary muscle requires a strongly acting cycloplegic to stay the accommodative power. In myopic eyes one of the stronger cycloplegics may be used to advantage, for the following reasons: Myopic eyes have large pupils, as a rule, and are not annoyed by the photophobia; myopic eyes are often in a state of irritation, and the drug gives

them a much-needed rest; the myope's distant vision is not disturbed by the cycloplegic, as in the case of the hyperope.

Whenever a cycloplegic is prescribed, the patient should be ordered a pair of smoked-glass spectacles to wear during the mydriasis. Of the two forms of smoked glasses—coquilles and plane—the latter should always be preferred, as they are without any refractive quality, whereas coquilles have some form of refraction that may act very injuriously. Another reason for ordering the plane glass is that the patient will often wish to wear them with his prescription glasses, which he could not do so well if they were coquilles. Dark glasses are of four shades of "London smoked"—A, B, C, and D; A being the lightest shade and D the darkest. The prescription would be:

For Mr. Brown:

℞. One pair plane London smoked "D."
Sig.—For temporary use.

March 14, 1910. Dr.——

The cycloplegics above mentioned for purposes of refraction are ordered in the following strengths:

Atropin. sulphatis	gr. j to aq. dest	f ℨij.
Duboisin. sulphatis	gr. ss to aq. dest	f ℨ ij.
Hyoscyamin. sulphatis	gr. ss to aq. dest	f ℨ iss.
Daturin. sulphatis	gr. ss to aq. dest	f ℨ ij.
Scopolamin. hydrochlor	gr. j to aq. dest	f ℨ j.

For young children these cycloplegics should be prescribed in half the strength just mentioned.

All these, except scopolamin, are ordered to be used three times a day, preferably after meals; but scopolamin being a very powerful drug, the surgeon should place it in the patient's eyes himself in the office, and not give a prescription for it. Only two drops are necessary, and are instilled a half-hour apart, the static refraction being estimated one hour after using the second drop.

Atropin Cycloplegia for Young Children.—In the writer's private practice when a young child is brought for the estima-

tion of a refractive error, one drop of a 1 per cent. atropin solution is instilled into each eye and the nasal ducts are carefully guarded for a minute or two afterward, and then dark glasses are adjusted, and the child and the mother or whoever brings the child are sent out for a walk for an hour. If the weather is not favorable, the patient waits for an hour in the waiting room and then the refractive error is carefully estimated with the retinoscope. It will be found that the ciliary muscle is entirely relaxed after this hour of waiting and no more atropin will be necessary (see page 295). The writer considers this the ideal way to use this drug in these young subjects. It avoids all danger of any toxic effect, it is a big relief to the mother not to put "drops" in the child's eyes at home and it certainly removes all danger of the drug getting into other hands. The dark glasses are not expensive; the writer always keeps them in his office and a pair is gladly donated to the little patient.

How to Use Homatropin.—This drug is expensive, and it is never necessary to prescribe more than one grain for any one patient. Personally, the writer has found the following most satisfactory, though the strength of the homatropin may be increased if desired:

For Miss Robinson:

℞. Homatropin hydrobromate.............................. gr. j.
Aq. dest.. ℳ xl.
M. Ft. sol. *Label*, poison drops!!
Sig.—One drop in each eye, as directed.
℞. Dropper. Dr.——

March 14, 1910.

One drop of this solution instilled into a healthy eye will produce mydriasis in a few minutes, but its action on the ciliary muscle is so trifling that the near point will be but slightly changed. It is thus shown that this drug is a decided mydriatic, and becomes a cycloplegic only under definite usage.

To produce cycloplegia with homatropin, the patient is given *the above* prescription and told to use it as follows:

To place one drop in each eye at bedtime the first night. This one drop dilates the pupil and establishes a change in the circulation of the blood-supply to the iris and ciliary body—a very important matter for the patient's comfort, and at the same time preventing a tendency to spasm of the ciliary muscle. The next morning one drop is to be placed in the eye every hour, from the time of rising until leaving home to go to the surgeon's office. At the office one drop is placed in each eye about every five minutes, until six drops have been used; then, after waiting half an hour (for the cycloplegic effect, which will last for one hour), the refraction is carefully estimated. After a short interval the cycloplegic effect will begin to rapidly disappear, so that the patient will be able to read within 48 hours' time with his correcting glasses.

Occasionally, a busy patient will insist upon having his eyes refracted during his first visit, and cannot take time to use the drops in the manner above suggested. The surgeon must, therefore, start and use the drops in his office. This is *forcing* the ciliary muscle into a state of rest that does not always give ultimately satisfactory results. "Forcing" homatropin into an eye in this way will always produce a "blood-shot" eye (hyperemia of the conjunctiva, etc.) that does not improve a patient's appearance, and it often produces severe neuralgic headache that may result in nausea or vomiting in occasional instances. Furthermore, it is possible, with a drug like homatropin, if not properly used, to have some of the sphincter-fibers become quiet while others may remain free to act. In this way a spasm of the ciliary muscle may be produced that will give a false astigmatism. Personally, the writer is not partial to this method of forcing the ciliary muscle into repose.

To somewhat obviate the "blood-shot" condition of the eye, and also to assist the action of the "forcing" process, one drop of a 2 or 4 per cent. solution of cocain may be instilled while the homatropin is being used. This also diminishes the danger of spasm. But cocain is objectionable in that it will, in some

cases, temporarily "haze" the cornea. The retinoscope will show this, and the patient will state that, while he can see the letters on the test-card, yet they have a "mist" over them. Instead of using the homatropin alone, a small amount of cocain may be added to the homatropin solution for the purpose mentioned. Or homatropin may be combined with cocain and chlorid of sodium in the form of a disc, and one of these, placed in the conjunctival sac, is allowed to dissolve and in this way quiet the accommodation. Or homatropin may be used in a solution of distilled castor oil. It is *claimed* that when the drug is used in this form, it remains in contact with the tissues and acts more energetically.

Homatropin as a cycloplegic should be held in reserve for individual cases, and not used as a routine practice. It is a good, reliable quieter of the accommodation in many eyes at the age of thirty-five or thereabouts, but in a young hyperopic eye it is a waste of time to attempt successful arrest of accommodation with it, and the danger of producing a false astigmatism should certainly deprecate its use in these cases. Another very serious objection to its use is that, before the eyes can become accustomed to the prescription glasses, the ciliary muscle recovers and begins to accommodate, with the result that the patient says he can see better at a distance without his glasses than he can with them, and has no small amount of mistrust of the surgeon's ability, as he will have to wear his glasses a long time before his ciliary muscle will relax its accustomed accommodative efforts. This is not nearly so likely to occur if one of the slowly acting cycloplegics is used.

Whenever homatropin cycloplegia is employed, it is good practice to instill a drop of eserin solution (grain i–℥j) into each eye before the patient leaves the office. This will counteract the mydriatic effect of the drug.

The method of refracting with one of the slowly acting cycloplegics, and then endeavoring to counteract the effect with a *solution* of eserin, is not recommended. Temporarily, eserin

may overcome the cycloplegic; but as its action is only transitory, the cylcoplegic effect reasserts itself and will not disappear until the specified time.

Refracting one eye at a time with a cycloplegic while the patient pursues his occupation with the other eye is not a method to be considered. This means a great amount of discomfort, headache, eye-strain, and even diplopia at times, during so prolonged a treatment.

If a hyperopic patient must occasionally use his eyes for near work while he has drops in them, a pair of +3 or +4 spheres may be given for temporary use.

Cycloplegia

Cycloplegia is a paralysis or paresis of the ciliary muscle. This condition may be monocular or binocular; it may be partial or complete. Mydriasis may or may not accompany the cycloplegia, though the two conditions usually occur together; and when they both exist, the paresis is spoken of as ophthalmoplegia interna. The ciliary muscle and sphincter of the iris are controlled by branches from the third nerve, but these branches are from independent centers; the fibers going to the ciliary muscle arise beneath the floor of the third ventricle, in front of the fibers which go to control the sphincter of the iris.

Causes.—Temporary arrest of the ciliary muscle and iris, as already stated, will result from the external or internal administration of a cycloplegic. It is interesting, in many cases, to find the cause and relieve the patient's anxiety when the paresis (temporary) is due to one of the cycloplegics. Aside from the use of eye-drops, the question of external medication (liniments, ointments, and plasters) should be inquired into, as also whether rectal or vaginal suppositories containing a cycloplegic have been used.

Other causes of this form of paralysis are tonsillitis, quinsy, diphtheria, Bright's disease, rheumatism, gout, exhausting

diseases, blows upon the eye, etc. Other and more serious causes, as controlling a guarded prognosis, are intracranial hemorrhage, meningitis, syphilis, brain tumor, etc. In some instances the cause cannot be definitely ascertained.

Symptoms and Diagnosis.—Photophobia, dilatation of the pupil, and loss of accommodative power consistent with the refractive condition of the eye.

A myopic eye retains its vision at the far-point only; an emmetropic eye or a hyperopic eye wearing correcting glasses has good distant vision and absence of a near-point; an uncorrected hyperopic eye has poor distance and near vision.

Prognosis.—This depends upon the cause.

Treatment.—This must be symptomatic and expectant, with a removal of the exciting cause, if possible. As many cases of cycloplegia are the result of, or follow, an attack of diphtheria, or a disease which has reduced the system below par, tonics, fresh air, etc., must be ordered. When brought on by syphilis, mercury and iodid of potash must be prescribed. Dark glasses for the photophobia should always be ordered, and lenses for near work may be worn as a temporary expedient. The use of eserin locally will occasionally do good work, but is *not* advised for constant use or for every case. Faradism may be used if the cycloplegia is very persistent, but the best results may be expected from systemic treatment. The use of strychnin or nux vomica is recommended in certain instances.

Cramp of the Ciliary Muscle

Cramp of the ciliary muscle is the opposite condition to that of cycloplegia, just described. Ciliary cramp may occur in one or both eyes, usually in both; it may occur in any form of ametropia or in emmetropia. Ciliary cramp is of two kinds—clonic and tonic.

Clonic cramp is an occasional and temporary condition which *comes on* while the eyes are in use, and passes away soon after

the eyes have had an opportunity to rest, and may not occur again for several days.

Tonic cramp, also called "spasm" of the accommodation, is a permanent condition as compared with the clonic form, and occurs whenever the eyes are used for distant or near vision. The patient cannot use her eyes for any length of time or with any considerable concentration without suffering as a consequence.

Causes.—Clonic cramp may occur as one of the early symptoms of presbyopia. Ametropia is a very common cause, and especially in cases of low amounts of hyperopia or myopia. Emmetropia, or eyes made emmetropic with glasses, may develop clonic or even tonic cramp if the eyes are used to excess or in a bad light. Such cases have been called "hyperesthesia of the retina." Tonic cramp may develop from the same causes which bring on the clonic form, and is usually seen among young hyperopic children, or the "pseudo-myope" already described. It also occurs occasionally in hysteric patients or those recovering from some severe or long illness. The writer has seen this form of cramp precede or antedate by several weeks a collapse of the nervous system—*i.e.*, nervous prostration.

Symptoms.—Naturally, ciliary cramp means ocular pains and headaches. "Opera headache," "train headache," "shopper's headache," "bargain-counter headache," etc., are some of the many names given to cramp of the ciliary muscle, and are, no doubt, the result of accommodative effort in a bright light or watching moving objects, these symptoms being a part of the history of accommodative asthenopia (already described) and accompanying insufficiency of the muscles. Symptoms of myopia are very evident during the cramp. In the tonic cramp the ocular pains and headache may be so excruciating in individual cases as to make the family physician and patient dread cerebral disease until the immediate cause is found out.

Treatment.—As the cause is usually one of ametropia, this must be corrected by the careful selection of glasses while the

eyes are undergoing a *prolonged* rest with a cycloplegic and dark glasses. Later on the patient must be cautioned against any overuse of the eyes. The general health should have any necessary attention. Sedatives, alteratives, and tonics have their place in individual cases. Reflex causes must be looked for and, as far as possible, removed. Insufficiencies should always be carefully searched for, and frequently prism exercises to develop the strength of the weak muscles may give marvelous results. Unfortunately, there are occasional instances of tonic cramp that persist in spite of any treatment, and such cases obtain relief only when presbyopia definitely asserts itself.

Asthenopia (from the Greek, ἀ, priv.; σθένος, "strength;" ὤψ, "eye") means a weakness or fatigue of the eye, applying especially to the retina, the ciliary muscle, the extra-ocular muscles, or a general weakness of any one or two or all of these structures in one and the same eye. *Asthenopia is a disease, and is often spoken of as "weak sight," eye-strain," or eye-stretching."*

Varieties.—For purposes of study, differential diagnosis, and treatment, asthenopia, or eye-strain, has been divided into the following varieties: Retinal, muscular, accommodative, and asthenopia due to a combination of any two or all three varieties.

Retinal Asthenopia.—This is a common form of asthenopia, and occurs more often in females. It is brought about by overuse of the eyes in too dim or too bright a light, and may result from a too prolonged use of the eyes at any kind of work or in any kind of light. It may result from exposure to the sun's rays, to electric lights, or to lightning, or by reflection from bright objects, such as snow, etc. Retinal asthenopia may occur as a *symptom* of hysteria, or in a patient whose nervous system is peculiarly susceptible to vibrations, sounds, and lights; in a patient whose nervous system is an uncertain quantity. Such patients are very unsatisfactory to treat or even to examine; they often imagine that the reflected light from the ophthalmoscope or retinoscope is "very hot," etc.

Symptoms.—The chief symptom is a dread of light (photophobia), or photophobia and lacrimation together.

Treatment.—The first thing to do is to remove the cause, if this can be found; otherwise the treatment should be very conservative. Ametropia must be corrected and the eyes be given some regular work; in other words, it is not good practice to restrict all use of the eyes. The treatment with "tinted glasses," made so much of by the charlatan to "gull" the innocent public, should not be ordered, as the patient grows accustomed to them and they eventually become an absolute necessity on all occasions. Careful attention to the general health is certainly indicated; tonics, out-door sports, etc., should be prescribed in individual cases. The shade of the trees is to be recommended in preference to the seashore and bright reflection from the sand and water.

Muscular Asthenopia.—This is due to weakness or fatigue of one or more of the extra-ocular muscles, most frequently the interni (exophoria). Muscular asthenopia of the exophoric kind is the result, as a rule, of a want of power to maintain convergence. The symptoms are in keeping with a cramp followed by a relaxation of converging power. Ocular pains, eyeballs tender to the touch (perchance the internal recti themselves become sore to the touch or feel sore on movement of the eyes), and in some cases the conjunctiva and subconjunctival tissues overlying the muscles become hyperemic during or after the use of the eyes, simulating rheumatism of these structures. In other cases dim vision and diplopia will be occasional manifestations. An occasional patient complains of seeing the nose. Patients with muscular asthenopia occasionally find that they can continue at near work by using one eye, but this does not occur very often.

Treatment.—This resolves itself into the correction of the ametropia, exercise of the weak muscles, etc. (see chapter on Muscles).

Accommodative Asthenopia.—This is by far the most common form of asthenopia, and is due to fatigue of the ciliary muscle; it is, therefore, to be expected in hyperopic eyes. It is caused in various ways: from overuse of the eyes in too bright or too dim a light, or from using the eyes for too long a time in any kind of light. The best pair of eyes, if overtaxed, may suffer from accommodative asthenopia, even when wearing the ametropic correction. Or accommodative asthenopia may result from a weakness of the ciliary muscle as a part of the general condition of the whole body, and this may come on after or during some long illness, such as typhoid fever. Accommodative asthenopia is often present in the early months of beginning presbyopia.

Symptoms.—The principal symptom is headache—frontal, fronto-temporal, or fronto-occipital—or this pain or discomfort may extend into the neck or between the shoulders. The headache develops during the use of the eyes, and grows worse if the effort is prolonged, and usually ceases after the eyes are rested. See chapter on Hyperopia and Myopia.

Treatment.—When glasses are necessary, they should be ordered by the static refraction. The general health of the patient should receive careful attention. An out-of-door life will often be necessary, and in certain cases the time for using the eyes at any near work will have to be very much restricted.

Accommodative with Muscular Asthenopia.—This variety of asthenopia embraces the two forms just mentioned, and its description and treatment are included in both.

Reflexes Due to Eye-strain.—Among the symptoms of the various forms of asthenopia described on the previous pages, the writer has avoided any decided reference to reflex symptoms, preferring to speak of these reflexes in a general way under one heading. Many patients who suffer from headaches, ocular pains, etc., during the use of their eyes, also very frequently suffer from constipation, indigestion, heartburn, nausea, or *even vomiting*. Other patients may have nervous attacks, a

fear of some impending calamity, or they are irritable or despondent; they may suffer from insomnia, or, if they sleep, it is not a restful sleep. Others may have epileptic attacks, nervous twitchings, etc. To just what extent eye-strain is responsible for these and many other reflexes the writer is not prepared to say, though every ophthalmologist has certainly seen *some* cases of accommodative and muscular asthenopia with gastric symptoms, or nervous symptoms, or epileptic attacks, or irritable tempers, or insomnia, or enuresis, etc., in which these reflex symptoms entirely disappeared after the eye-strain was properly treated.

Examination of the Eyes

A systematic method should be pursued in the examination of the eyes, and the results recorded in a book or on a card prepared for that purpose. The student should be a careful observer, and also be able to question the patient intelligently for short and definite answers. The following is an excellent method of making records, but there is no arbitrary rule, and in this respect each surgeon may follow his own desires:

Date..................................
Name..................................
Residence..............................
Occupation.............................
Age................ *Sex*.............. *Diagnosis*.....................

ACCOMMODATION ASTIGMATISM MUSCLES
O. D. V......................... p. p.
O. S. V......................... p. p.
History...........................
S. P. (*status præsens,* "present condition"). *Inspection*....................
Ophthalmometer, O. D.................... O. S...............
Ophthalmoscopic examinations, O. D.................... O. S.................
Manifest refraction. Fields. Color sense. ℞.

The above record is filled out as the examination proceeds, but it is not always advisable to follow the examination in the

order given; on the contrary, it is better, after getting the patient's name and address, to ask certain other questions which may appear in keeping with an individual case.

1. **Occupation.**—This is a very important question as bearing directly upon the amount and character of work done by the eyes; for example, writing, reading, sewing, music, engraving, weaving, drafting, surveying, painting, typewriting, typesetting, sorting colors, etc.

2. **Age.**—This is of the utmost importance in comparing the range of accommodation (near point) with the emmetropic condition. Knowing the patient's age and near point will often give a diagnosis of the character of the refraction.

3. **The name** tells the sex, but the question really is whether the patient is married, single, widow, or widower. If a young married woman, whether she is nursing a young child.

4. **History.**—Under this heading the questions should bear directly upon the eyes. "In what way do the eyes cause trouble?" The usual answer to this question is "*headache.*" To get a complete history of the headache, and be able to differentiate it from headache due to other causes, the succeeding questions seem appropriate:

What part of the head aches? Is it frontal, occipital, temporal, interocular, vertex, or all over the head?

When does the headache come on—during or after the use of the eyes? Does it cease *after* resting the eyes? Is the headache worse when using the eyes by artificial light? Is the headache constant? Is it periodic? Is it worse at a certain hour of the day? Is the headache present when first waking in the morning? Does the head ache during or after attending a place of public amusement or when shopping? If a female, is the headache only monthly?

The ophthalmologist must not think because a patient has a headache that it is surely and always due to the eyes, and that glasses are going to cure it. It is for the ophthalmologist *to find out* just what part the eyes take in causing the

patient's discomfort, and not always expect to cure with glasses headaches that have no direct relation to the eyes.

One of the most common of headaches which may be mistaken for ocular headache is the "brow ache" due to malaria, but a history of previous malarial attacks, chills and fever, a residence in a malarious district, and the fact that it is periodic in character, should certainly give a clear differential diagnosis.

Other patients may not consult the ophthalmologist on account of headache, but for a pain in or back of the eyes, or back part of the head, or between the shoulders, which comes on after any effort of vision. Others may complain of a feeling of sand in the eyes, or a burning in the lids, or a smarting or itching in the lid margins, or excessive lacrimation, or a feeling of drowsiness as soon as the eyes are used for any length of time, or a feeling as if the eyelids would stick to the eyeballs.

The patient's seeing qualities may develop the history of poor distant vision and good near vision, or *vice versa;* this should be inquired into very carefully, and it may be well to ask about other members of the family, if they have the same condition. Or a history of the vision gradually failing or of a sudden loss of sight may be obtained, and presbyopic symptoms should be referred to, if the patient is over 40 years of age.

If the patient wears glasses, a record should be made of the character and strength of the lenses, and whether the lenses were ordered with or without "drops" in the eyes; and if "drops" were used, if the effect lasted for two days or longer (slowly or quickly acting cycloplegic). Ask how long the glasses have been worn, and if the same symptoms are present that existed when the lenses were ordered.

Having made a note of the patient's history, it is next in order to study the present condition (*status præsens*):

1. Breadth of face, its symmetry or asymmetry; interpupillary distance.

2. The eyelids, whether swollen, discolored, or having red margins.

3. The eyelashes (cilia), whether regular, irregular, or absent. If there are chalazia, styes (hordeola), inflammation, moist or dry secretion at the roots of the cilia (blepharitis).

4. Inspect the inner surface of the lids and ocular conjunctiva for inflammation or growths.

5. Inspect the lacrimal apparatus in all its parts.

6. Inspect the cornea for its polish, transparency, and regularity.

7. Depth of the anterior chamber.

8. Iris, its color and mobility.

9. Pupil, its size, shape, and position.

10. Color of reflex from the pupillary area.

11. Palpate to measure the intraocular tension.

12. Use the cover test at 13 in. for any muscular anomaly.

Following this record of the history and present condition, the distant vision and near point are taken for each eye, one or more tests for astigmatism are made, the muscles are tested for distance (6 meters), and the ophthalmometric measure of corneal curvature may be recorded. Finally, and most important of all, the ophthalmoscopic examination is made, and the cornea, aqueous, lens capsule, lens, vitreous, nerve (shape, size, color, cupping, and vessels), conus, macular region, etc., and periphery of the eye-ground are studied. To accomplish all this it may be necessary to employ a weak mydriatic.

Lastly, fields and color sense, dynamic and manifest refraction.

CHAPTER XVIII

HOW TO REFRACT

General Considerations.—Before placing lenses in front of an eye, the surgeon should be acquainted with at least five important facts:

1. **The Patient's Age.**—This tells at once, from the table on page 108 (which the surgeon should commit to memory), what the near point will be if the eyes are emmetropic or standard.

2. **The Near Point.**—This will usually indicate hyperopia if beyond, and myopia if closer than, the emmetropic near point for the age. Of course, the near point will be deceptive if there is disease of the eye or any want of transparency in any of the media on the visual axis.

3. **The Distant Vision in Each Eye.**—If very defective, or if less than $\frac{VI}{VI}$ and near point closer than the age calls for, myopia is indicated. Good distant vision and near point removed indicate hyperopia.

4. **The distant vision, if recorded with question marks,** usually indicates astigmatism.

5. **The Results of Testing with the Astigmatic Chart.**—With the ciliary muscle at rest, darkest lines from XII to VI, or I to VII, or XI to V indicate astigmatism (myopic) with the rule; or darkest lines from IX to III, or VIII to II, or X to IV, indicate astigmatism (hyperopic) with the rule.

It is well to remember that about four patients out of five have hyperopia, or one patient in five has myopia, and the minus sphere selected almost invariably requires a cylinder in combination. Remember, also, that astigmatism is usually with the rule and symmetric, and that plus cylinders are generally selected at axis 90 or within 45° either side of 90, and minus

cylinders are generally selected at axis 180 or within 45° either side of 180.

The Placing of Trial-lenses.—1. These should always be placed as close as possible to the eyes without interfering with the lashes; and to accomplish this, the trail-frame should be easy of adjustment.

2. The most convex surface of any lens should be placed outward and the most concave surface inward, or to state the same fact in another way, the least convex surface of any lens should be placed inward and the least concave surface outward.

3. The center of the trial-lens must be opposite to the center of the pupil.

4. If the distant vision is very defective,—$\frac{VI}{XV}$, $\frac{VI}{XX}$, $\frac{VI}{XXX}$, $\frac{VI}{XL}$, or $\frac{VI}{LX}$,—a strong lens of 1 or 2 D. will often be required; whereas, if the vision is $\frac{VI}{VIIss}$ or $\frac{VI}{X}$, a weaker lens would be called for.

5. When a spheric lens placed before an eye improves the vision, it should not be changed for another unless the vision is made better by having its strength increased or diminished by placing in front of it another sphere (plus or minus) of less strength. For instance, if a +2 sph. has been placed before the eye and the vision is improved from $\frac{VI}{LX}$ to $\frac{VI}{VIIss}$; this +2 sph. should not be changed until a +0.50 or −0.50 sph. has been held in front of it, and the patient states whether he can read more with it or less without it. When a vision of $\frac{VI}{VI}$ is approximated, then its accuracy must be determined by placing first a +0.25 and then a −0.25 in front of the correction, so as to learn from the patient which one, if either, of these lenses improves the vision. Or if the correcting lenses selected are weak ones, then 0.12, plus and minus, may be used in place of the 0.25.

6. Spheric lenses should always be tried before using cylinders, and the vision brought as low as possible with a sphere before combining a cylinder, and, in fact, after the vision has been improved as much as possible with a sphere, the astigmatic chart may be brought into use as a guide for astigmatism, as

very often low errors are not recognized until this point in the refraction has been reached. Advocates of the ophthalmometer place the cylinder before the patient's eye and then add the spheric correction. The writer is not partial to this method or way of estimating the refraction.

7. When a patient miscalls one or more letters in a certain line, the surgeon must not hurry on until these are corrected by the patient with a suitable glass, and in this way the refraction is gradually worked out until the vision is brought to the greatest acuity possible. It is never wise to stop with a vision of $\frac{VI}{VI}$, as we are often able to get a visual acuity of $\frac{VI}{V}$ or occasionally $\frac{VI}{IV}$.

8. **Cylinders.**—When a plus cylinder is employed, it is placed with its axis at 90, and then slowly revolved (if necessary) to an axis where the patient says he can see better. A minus cylinder is placed at axis 180, and revolved in the same manner. The rule (5) for changing spheres also applies to cylinders; *i.e.*, to increase or decrease the strength of the cylinder by placing in front of it a plus or minus cylinder of less strength at the *same* axis.

9. **Axis of the Cylinder.**—When a patient is not sure about an *exact* axis, though he is sure that the cylinder improves the vision, then the surgeon may employ a sphere of the strength of the sphere *and* cylinder combined, and use a cylinder of the same strength as before, but with opposite sign and at about the opposite axis. For example, with +2.25 sph. ⊂ +0.75 cyl., the patient is not sure if the vision is best with the axis at 35, 40, or 45, the surgeon must then use a +3.00 sph. ⊂ −0.75 cyl., when the exact axis (at right angles) will usually be selected without any hesitancy or doubt.

10. **Proving the Correction.**—All tests at the trial-case, when a cycloplegic is used, should be confirmed, with the retinoscope.

11. **Crossed Cylinders** (Jackson's) (Fig. 293).—This is a trial-lens that has one meridian minus and the opposite meridian plus. They are made of any strength, but for general use the 0.25 cylinders are employed; *i.e.*, −0.25 sph. ⊂ +0.50 cyl.

The purpose of the crossed cylinders is to increase the refraction in one and diminish it in the opposite meridian. For example: if +2.00 sph. $\bigcirc$ +1.00 cyl. axis 90 gives a vision of $\frac{\text{VI}}{\text{VIIss}}$, and the crossed cylinder lens is placed in front of this combination with −0.25 at axis 180, and the +0.25 at axis 90, and the vision comes down to $\frac{\text{VI}}{\text{VI}}$, it shows that the vertical meridian was 0.25 too strong, and the horizontal 0.25 too weak, and the result would be +1.75 sph. $\bigcirc$ +1.50 cyl. aixs 90°. Or, if −3.00 sph. has brought the vision to $\frac{\text{VI}}{\text{IX}}$, and the crossed cylinder lens is placed before it and rotated to axis 15 for the minus cylinder and axis 105 for the plus cylinder, and the vision comes to $\frac{\text{VI}}{\text{VI}}$, the result would be −2.75 sph. $\bigcirc$ −0.50 cyl. axis 15.

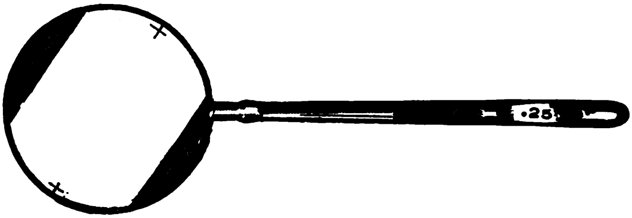


FIG. 293.

Summary.—The following is given as the various steps in refraction and the lens to be tried after the correction is supposed to be correct. For instance, if the patient sees $\frac{\text{VI}}{\text{VI}}$ with the following, +1.00 S. D. $\bigcirc$ +1.00 cyl. axis 90, this is not to be ordered until the various lenses have been successively placed in front of this correction to make sure that the eye will not accept some other combination.

+0.25 sphere.
−0.25 sphere.
+0.25 cylinder at same axis.
+0.25 cylinder at opposite axis.
−0.25 cylinder at same axis.
−0.25 cylinder at opposite axis.
crossed cylinder lens.

The Pinhole Disc.—Fig. 100. The purpose of the pinhole disc when placed in front of an eye is to thus artificially reduce the size of the pupil and cut off peripheral rays. This disc is so called because it is made of sheet metal, the diameter of the ordinary trial-lens, and has at its center a round opening the size of the shaft of an ordinary pin, *i.e.*, 1 mm. in diameter.

The specific purpose of this disc is to indicate in an eye with subnormal visual acuity, whether this reduced vision is caused by a refractive error, opacities in the media or to pathologic changes at the macula. Ordinarily (but not always) if the pinhole disc improves the vision of an unglassed eye, the lenses if properly selected will improve the vision just as much if not more than that obtained by the addition of the disc. The reader must bear in mind that there are some eyes in which the pinhole disc improves the vision and lenses will not; this latter is due to irregular refraction, the refraction at the center of the pupil being different from that at the periphery, namely, in cases of conic cornea, opacities in the cornea and opacities in the lens. In cases of pathologic changes at the macula of the eye, the pinhole disc will not materially improve the vision.

Methods of Estimating Refraction.—To determine the refraction of an eye it may or may not (as in presbyopia) be necessary to employ a cycloplegic. When the refraction is estimated without a cycloplegic, it is spoken of as manifest or dynamic (Gr. δύναμις, "power") refraction. When a cycloplegic, is used, the refractive estimate is spoken of as static (Gr. στατικός, from, ἱστάναι, "to stand at rest"). In one instance the ciliary muscle is permitted to act, and in the other it is at rest. A third method is to obtain the static refraction and then to estimate the strength of the glasses to be prescribed *after* the effect of the cycloplegic has passed out of the eyes; this is spoken of as postcycloplegic refraction. Eyes for refraction are divided into two general classes, according to the age of the patient. In those under 40 years of age a cycloplegic is usually employed,

but after this age a cycloplegic is often dispensed with (see Presbyopia).

Fogging Method.—This method simulates the static or cycloplegic method, as the ciliary muscle is in great part placed artificially at rest by having in front of the eye under examination *a plus sphere of sufficient strength to more than overcome any ciliary muscle power that the eye might otherwise use when looking at a distance of* 6 *meters.* The "fogging" method is so called because distant vision is made obscure or "foggy." The eye under examination with this strong plus sphere in front of it is, to all intents and purposes—for the time being, at least—myopic. If plus spheres are added until the eye is overcorrected, then looking at the distance test chart, the desire to see as clearly as possible will cause the ciliary muscle to relax and the disturbing effect of the accommodation is eliminated. This fact should be carefully borne in mind, as the method to pursue in estimating the refractive error is to proceed the same as in any regular case of myopic refraction. Therefore, this method is only of occasional service in estimating the refraction of eyes that have some form of hyperopia or simple myopic astigmatism, and is not of service in myopia or compound myopia.

How to Proceed in Hyperopia.—Having estimated with the ophthalmoscope that the eye is hyperopic about 2.50 D., then place a +4D. sphere before the eye and have the patient look at the card of test letters at a distance of 6 meters. This has the immediate effect of making distant vision very "foggy," but by waiting a few seconds this foggy vision will clear slightly and the ciliary muscle will relax a part of its effort to accommodate. Then proceed as if refracting a myopic eye by placing a −0.50 sphere in front of the +4 D. sphere, and gradually increase the strength of the minus sphere until the patient reads $\frac{VI}{VI}$. If the minus sphere is 1.25 D., then the amount of the hyperopia will be +2.75 D., which is the difference between the +4 D. and the −1.25 D.

How to Proceed in Simple Hyperopic Astigmatism.—Having estimated with the ophthalmoscope or retinoscope or ophthalmometer or any of the various ways that the eye has hyperopic astigmatism of about 2.50 D., proceed as in hyperopia by making the eye myopic by the addition of a +4 D. sphere. Have the patient look first at the card of test letters and make a record of the visual acuity, then at an astigmatic clock-dial close to the letters. Proceed by adding minus spheres as in the previous case, and as soon as the patient recognizes one series of lines on the clock-dial as much darker than all the other lines, then place minus cylinders in position with their axes at right angles to the darkest lines, and as soon as the lines are uniformly black on the dial then have the patient look at the test letters again and increase the strength of the minus sphere if necessary until the eye can read $\frac{VI}{VI}$ or $\frac{VI}{V}$. Presuming that −2 sphere and −2 cylinder at axis 180° were used, then the difference between these and the +4 sphere would give +2 cylinder, axis 90, as the amount of the hyperopic astigmatism.

How to Proceed in Compound Hyperopic Astigmatism.—If the meridian of highest refraction is 4 D., then place a +5 D. sphere before the eye, wait a few seconds, then begin by adding minus spheres until a series of lines on the clock-dial show up very black, then add minus cylinders until all the lines become uniformly black, then turn to the test letters and increase the strength of the minus sphere as necessary until the vision is brought to normal. With +5 D. sphere before the eye and if −1 sphere and −3 cylinder at axis 165 were employed, then the compound hyperopia would be +1 sphere with +3 cylinder at axis 75.

How to Proceed in Mixed Astigmatism.—Estimating the refraction approximately as +1 ○ −3 cylinder; place +4 D. sphere in position as before, then find the meridian of darkest lines on the clock-dial, add minus cylinder with the axis at right angles to the darkest lines, then when all lines are equally black, diminish the strength of the plus sphere until vision comes

to the normal, if it is possible to get it to this point. The result may be $+4$ sph. $\bigcirc$ -2.50 sph. $\bigcirc$ -3.50 cyl. $\times$ 180, which would equal $+1.50$ $\bigcirc$ -3.50 cyl. $\times$ 180°.

Advantages of the Fogging Method.—It is one of the best approximate ways of estimating the refraction if for any reason a cycloplegic cannot be employed, as in cases of glaucoma, nursing mothers, or of an individual who may have an idiosyncrasy for a cycloplegic. The fogging method also has the advantage, like the cycloplegic method, of uncovering or bringing out considerable of the latent hyperopia.

Manifest or Dynamic Method.—This method is the very reverse of the "fogging" method, in that the refraction is estimated without first making the eye artificially myopic or placing the ciliary muscle at rest. It is, therefore, a method that is liable to give all sorts of erroneous results if the subject is hyperopic and less than 40 years of age.

To estimate the refraction by the manifest method, the patient is told to look first at the test letters and then at the clock-dial at 6 meters distance; the astigmatism is corrected and then plus or minus spheres added as necessary to bring the vision to the normal. The rule is to employ the strongest plus lenses or the weakest minus lenses which will give normal vision.

Advantages of the Manifest Method.—This is the method by which the eyes of patients past 45 years of age are often refracted; a fairly good method in cases of compound myopia in young subjects if, for any reason, drops cannot be employed.

Objections to the Manifest Method.—It is not a method to be used as a rule in young subjects. If a young subject must be refracted without drops on account of some local or constitutional disease, then the fogging method should be followed.

The habit of prescribing glasses from the manifest or "fogging" method without any knowledge of the ophthalmoscopic findings is not a method that merits the attention of the conscientious physician. Such work is very unsatisfactory,

often leading to gross errors, ultimate dissatisfaction on the part of the patient, or injury to the eyes, and the only way to make a satisfactory study of the interior of the eye is by dilating the pupil.

Postcycloplegic Refraction.—The ordering of glasses after the static refraction has been recorded and the effect of the cycloplegic has left the eyes. For instance: While the ciliary muscle is at rest with atropin, the static refraction is found to be $+1.50$ sph. $\bigcirc$ $+2.00$ cyl. axis $90°$, which gives a vision of $\frac{\text{VI}}{\text{V}}$. The atropin is then stopped and the patient told to report in 15 days, when the ciliary muscle will have regained its original strength and gone back to its old habit of accommodating for distance. The static refraction is place before the eyes, and the strength of the sphere is gradually reduced until the vision just equals $\frac{\text{IV}}{\text{V}}$, as it was when the "drops" were in the eyes. Whatever this correction with the glasses may be, is ordered. Occasionally, though very rarely, the strength of the cylinder as well as its axis is also changed. Eyes that require any such changes in the cylinder usually have some opacity in the cornea or lens, or conic cornea.

Objections to the Postcycloplegic Method.—The patient is annoyed by the long delay to which he is subjected before getting his glasses. But the principal fault lies in the fact that the eye is not placed in the emmetropic condition; it is allowed to retain more or less of its accommodative power for distance.

Static Refraction.—By this method the glasses are prescribed while the ciliary muscle is under the effect of the cycloplegic. In hyperopia allowance must be made in the strength of the sphere for the distance at which the test is made. At 6 meters 0.25 is deducted from the sphere without any change in the cylinder. The only possible objection to this method is in cases of hyperopia, in which, after the effect of the cycloplegic passes away, the ciliary muscle may endeavor to accommodate for distance with the glasses in position, and with the result that the patient cannot see clearly except near at hand. To avoid

any such contingency the surgeon will have to make a deduction in the strength of the plus sphere to meet such cases. The rule for ordering glasses by the static refraction in hyperopia is to deduct 0.25 from the sphere and have the glasses worn at once and constantly while the effect of the "drops" is gradually leaving the eyes. In this way the eyes grow accustomed (slowly) to seeing at a distance without exerting the ciliary muscle; the eyes are thus placed in an emmetropic condition. If this effect of the cycloplegic passes away before the patient can obtain the glasses, it will be necessary to use the drops for a day or so after the glasses are received. Unfortunately, however, some hyperopic eyes, in young subjects especially, with vigorous ciliary muscles, will develop a spasm of the accommodation for distant vision which will make the glasses very annoying on account of distant objects looking "dim." Such patients should be advised of this fact at the time the glasses are ordered, and if dim distant vision does develop, that it will be transitory, and to persist in wearing the glasses. There are two ways of relieving this "dim" vision if it should occur:

1. To prescribe a weak solution of atropin (1/20 of a grain to 1 fluidounce), one drop in each eye once or twice a day, the idea being to slightly relax the accommodation; this *is* accomplished, but, unfortunately, the mydriatic effect is a disturbing element which the patient will not submit to long enough, as a rule, to obtain relief.

2. The best way is to make a compromise in the strength of the sphere. An eye which has been in the habit of accommodating 2 or 3 diopters for distance, does not often give up this habit very gracefully, even if assisted by a slowly acting cycloplegic, so that when the static refraction calls for more than 3 diopters, the surgeon is frequently compelled to make a deduction of more than 0.25. Glasses may be ordered as follows: the surgeon being guided in great part by the (1) patient's age, and (2) occupation; also (3) as to whether there is esophoria or *exophoria*. It will be found that cases of esophoria will accept

almost a full correction, whereas cases of exophoria will require a very liberal deduction in the strength of the glass, the patient being allowed to use his relative hyperopia.

It is true that glasses ordered in this way do not leave the eyes in an emmetropic condition, and that, later on, when asthenopic symptoms redevelop, the strength of the glasses will have to be increased. But this method has two advantages: first, it gives the patient his glasses without any long delay, and the eyes have an opportunity to become accustomed to them while the effect of the "drops" is passing away; and, second, the patient accepts a much stronger glass in this way (than by the postcycloplegic method), which is a decided advantage.

The ordering of lenses in low errors for distant vision depends entirely upon the condition of the patient's eyes and symptoms. It is not unusual to find the most distressing asthenopia, headaches, blepharitis, etc., disappear as if by magic when corrections are ordered for small defects, especially if there is astigmatism. In other instances slight ametropic errors may not produce any unpleasant symptoms, and such a patient need not wear the correction for distance.

The Ordering of Glasses in Myopia.—There is no fixed rule for prescribing glasses in myopia. Each case is a law unto itself, and should receive the most careful consideration from every point of view. But as the student must have some idea as to how to proceed, the writer would suggest the following subdivisions:

1. Myopic eyes which can with safety use one pair of glasses for distant and near vision.

2. Myopic eyes which require two pairs of glasses—one for distant vision, and another pair for near-work, reading, writing, etc.

3. Myopic eyes which should have the near correction only.

Class 1 comprises those cases in which there is an active ciliary muscle, and the ophthalmoscope shows but little, if any, change

in the eye-ground indicative of stretching (children, or in beginning myopia). Glasses carefully selected by the static refraction may be ordered in such instances for constant use, but with the distinct understanding that if any discomfort arises at any time they will be subject to change.

Class 2.—Adults who have not previously worn glasses. In these cases the power of the ciliary muscle is weak, deficient in circular fibers, and, if forced into activity, the patient will be very uncomfortable, the eye will stretch, and the myopia increase, the tissues in these eyes yielding more readily than in Class 1. The glasses selected by the static refraction may be prescribed for distance, but a second pair, 1, 2, or 3 diopters weaker, must be ordered for the reading, writing, or working distance, that the accommodative effort may in great part be kept in abeyance. Class 1, if not carefully watched, may pass into Class 2 and Class 2 may pass into Class 3.

Class 3.—These cases require unusually strong lenses, and it is to these especially that the term "sick" or "stretched" eye particularly belongs. The ophthalmoscope may show vitreous opacities, areas of retinochoroiditis, macular choroiditis, a broad myopic conus, and even posterior staphyloma. The eyes are prominent, occupying much of the orbital space. Eyes of such length are limited in their power of comfortable rotation, and hence it is common for one eye to diverge, the patient stating that he uses only one eye for near vision. The diverging eye is usually more or less amblyopic, due to want of use or pathologic changes, or to both. Such eyes have lost almost or quite all the power of accommodation. These eyes must be placed in such a condition that the desire to converge and accommodate is at a minimum. The prescribing of glasses for these long eyes must be limited to the one pair for near-work, and yet the patient may, by bringing the glasses closer to the eyes, improve the distant vision for the time being—a sort of artificial accommodation. To appreciate what is meant by this statement it is necessary to reconsider the optics of a myopic

eye. A myopic eye of 20 D. has a far point of 5 cm., and the minus lens required to make such an eye receive parallel rays of light at a focus upon its retina should be of such strength that the rays passing through it would have a divergence as if they came from this far point (5 cm.). Such a lens would be a -20 D. This means, of course, that the -20 D. would have to be placed with its surface against the surface of the cornea, which is an impossibility. The usual distance for a lens in front of the eye is 1 or 1½ cm., so that this distance must be subtracted from the distance of the far point. In this instance 1 cm. from 5 cm. would leave 4 cm., and this would represent 25 D. As just stated, the glasses for this class of patients are limited to the one pair for near-work, and therefore it would be necessary to reduce the strength of these lenses 4 diopters and thus prevent, as far as possible, any accommodative effort. The patient using this -21 D. for near, can, if he wishes, improve his distant vision at any time by pressing the lenses closer to his eyes. The strength of concave lenses increases as they are brought closer to the eyes, and diminishes as they are removed from the eyes.

Caution.—The great danger in any refraction at the trial-case, but especially in myopia, is an over-correction, and this is very likely to occur if the surgeon is not extraordinarily careful in having his lenses placed as close to the eyes as possible while making the test.

Prophylaxis.—The prescribing of glasses for myopic eyes is only a part of the general treatment to which these "sick" eyes are entitled. If the treatment stops at this point, then the glasses may be an injury instead of a blessing. Myopia once established may pass through the various classes already described, and eventuate in greatly reduced vision or total blindness if certain limitation of their use is not insisted upon.

1. **Light.**—The patient should be supplied with a good, clear, and steady light which is always important; it should come from the left side, never from in front. A dark green shade

over the light (student's lamp or electric globe) is absolutely essential.

2. **Time.**—The length of time that myopic eyes may be used should be restricted as much as possible, consistent with their condition; that is to say, they should never be used after they become the least fatigued, and any use of the eyes should be counteracted by life in the open air.

3. **Attitudes.**—The head should have as little inclination as possible in reading, writing, or close work, as so faulty a position invites a congestion of the intra-ocular tissues. At school or at home the book should be inclined, and its distance from the eyes be regulated by the size of the patient.

4. **Print.**—The use of small print or minute objects must be forbidden. English or Gothic type should be substituted for Greek, German, and other characters. Fine needle-work, embroidery, etc., must be abolished. If necessary, music notes must be given up entirely. The paper of the books or magazines should never be glazed. Moving pictures are an irritation to the best of eyes.

5. **Health.**—The health of the patient must be looked after, and all irregularities corrected—constipation, etc.

These are a few of the major considerations to which the patient's attention must be drawn, the surgeon being limited in his remarks to the exigencies of the individual case.

In conclusion it may be well to know how myopia is produced, since it has been stated that the condition is rarely seen in young children. It is well known that astigmatism (hyperopic) is a congenital defect, and with this in mind it is very easy to appreciate the succeeding steps which lead to the compound myopic condition, showing at the same time the reason why *simple* myopia is so rare an anomaly.

Take a child six years of age who has a compound hyperopia of say $+0.50$ sph. $\bigcirc$ $+0.75$ cyl. axis $90°$; this child enters upon its course of study without any correcting glasses, and is subjected in its pursuit for knowledge to a faulty school desk

and chair, possibly facing a window. The print is defective in many ways. The artificial light for home study in the evening may be of poor quality, and so placed that but few of its rays fall upon the child's book. With these and other hindrances the eyes are strained (stretched). The tissues are very yielding in their growing state, so that at the age of 10 years the refraction may show $+0.75$ cyl. axis 90. The $+0.50$ sph. (the axial ametropia) has disappeared by an elongation of the optic axis. The vertical meridian is now emmetropic. The same conditions exist for the next three years, during which the number of studies is multiplied and the hours for study are prolonged and the child reaches the age of puberty; the refraction is now found to be -0.50 sph. $\bigcirc$ $+0.75$ cyl. axis 90°, mixed astigmatism. In two years more the refraction is found to be -0.25 sph. $\bigcirc$ -0.75 cyl. axis 180; *i.e.*, compound myopic astigmatism. From this time forward these eyes progressively stretch and are subject to the stretching process unless the progress is stayed with glasses and prophylactic treatment.

In the brief detail of this one case the student will fully appreciate another important fact—that the vertical meridian of the cornea, as a rule, maintains throughout the shortest radius of curvature. This is abundantly demonstrated by statistics.

The following summary of refractive errors and direction of meridians of shortest radius of curvature in 2500 pairs of eyes—1300 in private and 1200 in hospital work—prepared by Dr. Risley and the writer, shows the correctness of the above statements:[1]

[1] This report was read in the Section on Ophthalmology at the forty-sixth annual meeting of the American Medical Association, at Baltimore, Md., May 7 to 10, 1895.

	Private		Hospital	
		Per cent.		Per cent.
Monocular astigmatism	70	5.0	94	7.8
Binocular astigmatism	1151	88.5	828	69.0
Total cases	1221		922	
Binocular symmetric astigmatism	694	60.2	613	74.4
Binocular asymmetric astigmatism	310	26.8	158	19.8
Heteronymous astigmatism	123	10.6	40	5.2
Homonymous astigmatism	24	2.1	17	1.2
Total binocular astigmatism	1151		828	
Symmetric astigmatism:				
(*a*) According to rule (homologous)	543	78.2	559	97.7
(*b*) Against rule (heterologous)	151	21.8	54	2.3
Total symmetric astigmatism	694		613	
Asymmetric astigmatism:				
(*a*) According to rule	223	71.8	126	79.1
(*b*) Against rule	87	28.2	32	20.9
Total asymmetric astigmatism	310		158	

Direction of the Meridian of Shortest Radius in all Cases of Symmetric Astigmatism

	Per cent.
Meridian at 90°	57.0 +
Meridian inclined 15° or less on each side	19.7 +
Meridian inclined from 15° to 30° on each side	4.0 −
Meridian inclined from 30° to 45° on each side	1.0
Meridian at 180°	12.0
Meridian inclined 15° or less on each side	4.0
Meridian inclined from 15° to 30° on each side	2.0
Meridian inclined from 30° to 45° on each side	0.5

CHAPTER XIX

APPLIED REFRACTION

In estimating the refraction of any eye the surgeon will do good work if he will make it a rule never to be satisfied until each eye has a vision of $\frac{VI}{VI}$ or more, and if this visual acuity is not attained, to understand the reason why: whether it is his fault or the fault of the eye itself. It is most essential in every instance to have the good-will of the patient.

The following cases are detailed so as to demonstrate each form of ametropia in all its phases:

Case I.—Simple Hyperopia.—This is a common form of ametropia, occurring about 20 times in 100 cases:

January 3, 1910. JOHN SMITH. Age, 20. Single. Stenographer.

O. D. $\frac{VI}{IV}$. p. p. = type 0.50 D. at 12½ cm.

O. S. $\frac{VI}{IV}$. p. p. = type 0.50 D. at 12½ cm.

Add. = 22°; abd. = 6°.

History.—Frontotemporal headaches almost constantly, but much worse when using eyes at near-work. Had severe headaches when a school-boy. Never liked to study; preferred out-of-door sports.

S. P.—Face symmetric, but narrow. Blepharitis marginalis. Irises blue. Pupils round, 3 mm. in diam. Eyes fix under cover.

Ophthalmometer.—Each eye 0.25 axis 90°.

Ophthalmoscope.—Both eyes the same. Media clear. Disc small and round, with physiologic cup. All vessels near the disc are seen clearly with + 2 S. Eye-ground flannel-red and accommodation very active.

Manifest or dynamic refraction:

O. D. $+1.25$ S. $= \frac{VI}{IV}$.
O. S. $+1.25$ S. $= \frac{VI}{IV}$.

℞. Atropin and dark glasses for refraction.

January 5, 1910. Patient seated at 6 meters from test-card and small point of light. O. D. V. $= \frac{VI}{XXX}$ = O. S. V. $\frac{VI}{XXX}$.

Retinoscope, with $+3$ S., developed point of reversal at 1 meter for each eye.

With trial-lenses, O. D. and O. S. each select $+2$ S., which gives a vision of $\frac{VI}{IV}$, and they positively refuse to see $\frac{VI}{IV}$ clearly with an addition of $+0.25$ S. In other words, this $+2$ S. is the *strongest* lens which each eye will accept and maintain clear distant vision. *The rule for refraction in hyperopia is to employ the strongest lens which the eye will accept without blurring the distant vision.*

To prove that the ciliary muscle is at rest, and that the glass selected is correct, add a $+4$ S. to the distance correction, and the rays of light emerging from the eye must focus at the principal focus of the added $+4$ S., at 10 in. (25 cm.); and if the patient can read fine print at this distance, the ciliary muscle is at rest and the glass correct. If a $+3$ S. had been added instead of a $+4$ S., then the principal focus would be at 13 in.; if $+5$ S., then at 8 in., etc.

The question is, What glasses shall be ordered? The writer would give the following prescription, and instruct the patient to stop the drops and wear the glasses constantly:

For Mr. Smith.

℞. O. D. $+1.75$ sph.
O. S. $+1.75$ sph.

Sig.—For constant use.

January 7, 1910.

January 8: Glasses from the optician neutralize; are centered and accurately adjusted.

January 21: Add. = 18°. Abd. = 6°. Near-point in each eye = 10 cm. No headache or discomfort of any kind.

Considerations.—The static refraction as represented by +2.00 sph. means that rays of light which pass through this lens and focus at the fovea diverge from 6 meters' distance, which heretofore we have considered for purposes of calculation as parallel; but when glasses are ordered, allowance must always be made for this small amount of divergence, and so 0.25 is deducted from the +2 sph., that the eye may have parallel rays focusing on its retina when looking beyond a distance of 6 meters. To have been mathematically exact, +0.12 should have been deducted in place of +0.25.

The *purpose* in all cases of refraction is to place the eye in an emmetropic condition, though this is not always advisable in every instance. The hyperopic eye naturally accommodates for distance, and the emmetropic eye does not; then the hyperopic eye is made emmetropic when a spheric lens permits parallel rays to focus upon its fovea without any assistance whatever from the ciliary muscle.

Advantage of Atropin in this and Similar Cases.—The glasses are ordered while the ciliary muscle is at rest. The accommodation returns gradually. The eye becomes accustomed to seeing at a distance without the assistance of the ciliary muscle. Atropin produces a physiologic rest, which the overacting ciliary muscle, disturbed choroid, and irritated retina require. None of these good results can be expected in a case of this kind from the use of a "quick" cycloplegic like homatropin.

Summary.—Age of patient, 20 years. Amplitude of accommodation is 10 D. for this age.

Near-point is 12½ cm., which shows only 8 D.

Facultative hyperopia (Hf.) equals difference between 10 and 8 D., which is 2 D.

Manifest hyperopia (Hm.) equals 1.25 D.

Total hyperopia, or static refraction (Ht.), equals 2 D.

Latent hyperopia (Hl.) equals the difference between the manifest and total, 2 D. and 1.25 D., making 0.75 D.

The far-point, or conjugate focus, is negative or virtual, and lies back of the retina, where the emergent rays (diverging) from the eye would meet if projected backward; this point corresponds to the principal focus of the lens which corrects the hyperopia; *i.e.*, in this instance, +2 D., and the negative far-point is therefore at 20 in.

The +1.75 makes the eye practically emmetropic; the near-point, after the effect of the atropin passes away, is 10 cm., which is the emmetropic near-point for the patient's age. The plus sphere selected represents a shortening of the eye of ⅔ mm., as measured on the optic axis.

Case II.—Simple Myopia.—With the one exception of emmetropia, it will be found that myopia, plain and simple, without astigmatism, is one of the *rarest* conditions of the eye which the surgeon will meet in careful refraction work. About 1½ per cent. of all patients, by careful refraction, are found to have simple myopia. Therefore the condition is not common.

January 3, 1899. MISS RARE. Age, 25 years. Single.

O. D. V. = $\frac{VI}{LX}$? p. p. = type 0.25 D. at 9 cm.; p. r. at 40 cm.

O. S. V. = $\frac{VI}{LV}$? p. p. = type 0.25 D. at 9 cm.; p. r. at 40 cm.

Add., 16°. Abd., 6°. Exophoria, 3° at 13 in.

History.—Does not suffer much from headache, but eyes ache after any prolonged use at near-work. Never able to see well at a distance. Always stood high in her class at school, though she had to have a front seat to see the figures and writing on the blackboard. Has excellent vision for near-work and does fine embroidery. Has been accused of passing friends on the street without speaking to them. If she drops a pin on the floor, has to get on her knees to find it. Parents do not wear glasses. Grandfather had "elegant" sight, had "second sight," and never wore glasses. Patient has postponed getting glasses because parents objected.

S. P.—Face symmetric. Interpupillary distance, 65 mm. Irises dark. Pupils large, round, 5 mm. Eyes out under cover.

Ophthalmometer.—Each eye 0.25 axis 90.

Ophthalmoscope shows each eye the same. Media clear. Disc large and round. Shallow physiologic cup. Narrow myopic conus at temporal side of disc. Choroidal vessels seen throughout periphery of eye-ground and extending almost to nerve margin. All vessels near nerve-head seen with -3 S.

Manifest Refraction.—Each eye -3.00 sph. gives vision of $\frac{VI}{VI}$.

℞. Atropin and dark glasses for refraction.

January 5, 1899: Patient seated at 6 meters from test-card. O. D. and O. S. vision equals $\frac{VI}{LX}$. Retinoscope with -1.50 S. develops point of reversal at 1 meter for each eye. It will be noticed that the vision in hyperopia with and without drops is decidedly different, whereas in myopia there is little, if any, change. With trial-lenses each eye selects separately -2.50 sph., which gives a vision of $\frac{VI}{VI}$. If a -2.25 sph. is substituted, the vision falls to $\frac{VI}{VIISS}$. If a -2.75 is employed, the vision remains $\frac{VI}{VI}$, but the letters look small, black and "far away." The rule for refraction in myopia is to employ the *weakest* lens through which the eye can still maintain clear, distant vision.

What Glass to Order.—The writer would give the following prescription and instruct the patient to stop the drops and wear the glasses constantly:

January 7, 1899. For Miss Rare.

℞. O. D. -2.50 sph.
O. S. -2.50 sph.

Sig.—For constant use.

January 9: Glasses neutralize; are centered and accurately adjusted. Add., 18°. Abd., 10°. Patient is delighted with glasses.

January 21: Near-point, 12 cm.

Considerations.—As a rule, concave lenses are ordered without any deductions for the slight amount of divergence of the rays of light for the distance (6 meters) at which the estimate is made. To be exact, -0.25 should be added to the -2.50 sph. in this case; but the surgeon must avoid the danger of *over*-correcting the myopic eye, and, to be on the safe side, the glass is usually ordered as the patient selects and the retinoscope confirms it. These lenses make the eyes, to all intents and purposes, emmetropic. If at any time a myope wishes to obtain the effect of a slightly stronger correction, this can be obtained by turning the head and looking through the edge of the glasses which are stronger (sphere) at the edge than at the center.

Advantages of Atropin.—The choroid and retina are given a physiologic rest that they could not obtain in any other way. The patient will not select too strong a glass, as was the case in this very instance when manifested. Myopic eyes usually have large pupils and do not suffer, therefore, from mydriasis to the same extent as hyperopic eyes. The far-point remains unchanged. The power of convergence is somewhat relieved by the glasses, which at the near-working distance are of the nature of prisms, bases in.

Summary.—Age of patient is 25 years. Amplitude of accommodation at this age is 8.5 D. Near-point, 9 cm. = 11 D., and far-point, 40 cm. = 2.50 D. Difference between near-point and far-point in diopters = 8.50 D., which is the amplitude of accommodation for the patient's age.

Difference between the near-point in diopters (11 D.) and the amplitude (8.50 D.) is 2.50 D., which is the amount of the distant correction needed. With glasses on, the near-point, after the effect of the atropin passes away, is 12 cm., which represents the emmetropic near-point for the age. This myopia of 2.50 D. represents an eye nearly 1 mm. longer than the standrad eye, as measured on the optic axis.

Case III.—Simple Hyperopic Astigmatism.—Not an uncommon condition. About 5.5 per cent. of all eyes have this form of refraction.

April 3, 1899. MISS ROBINSON. Age, 24 years. Single. Dressmaker.

O. D. V. = $\frac{VI}{IX}$???. p.p. = type 0.50 at 13½ cm.

O. S. V. = $\frac{VI}{IX}$???. p. p. = type 0.50 at 13½ cm.

Add., 23° Abd., 5°. At 6 meters, esophoria 4°; at 13 in., 10° exophoria.

Astigmatic clock-dial shows darkest lines from X to IV with O. D.

Astigmatic clock-dial shows darkest lines from VIII to II with O. S.

History.—Headache every day; seldom entirely free from ocular discomfort. Distress begins in the forehead and extends to the back of the head and into the neck. After a hard day's sewing, has to go to bed and bind the head with a handkerchief. Once a week has a "sick headache," when she has to give up work entirely and take headache powders. Sick headache often ceases after emesis.

S. P.—Face symmetric. Blepharitis well marked, with many cilia missing. Edges of lids thickened. Irises light blue in color. Pupils apparently oval in vertical meridian. Corneal reflex shows axis inclined from vertical in each eye.

Ophthalmometer.—O. D., 1.50; axis 75, with the rule; O. S., 1.50; axis 105°, with the rule.

Ophthalmoscope.—O. D., vertically oval nerve axis, 75°. Accommodation very active. Underlying conus down and out. Vessels at 75 best seen with +1.50, and at axis 165, without any lens. O. S., same general conditions as in O. D. Vertically oval axis, 105. Vessels at 105° seen with +1.50, and at axis 15 seen without any lens.

Manifest Refraction.—

O. D., +1.25 cyl. axis 65° = $\frac{VI}{VI}$???.

O. S., same cylinder with axis 125°.

℞. Hyoscyamin and dark glasses for refraction.

April 5: 6 meters from test-card and point of light.

O. D. V. = $\frac{VI}{XX}$???.
O. S. V. = $\frac{VI}{XX}$???.

Clock-dial shows the same as at first examination.

Stenopeic Slit.—O. D., axis 75 with +0.25 S., V. = $\frac{VI}{VI}$; and at axis 165 with +150 S., V. = $\frac{VI}{VI}$. O. S., axis 105 with +0.25 S., V. = $\frac{VI}{VI}$; and at axis 15 with +150 S., V. = $\frac{VI}{VI}$.

Retinoscope at 1 meter shows: O. D., at axis 75° +1.25 S., and axis 165°, +2.25 S. O. S., at axis 105°, +1.25 S., and at axis 15°, +2.25 S.

At Trial-case.—

O. D. + 0.25 sph. ◯ +1.00 cyl. axis 75°, V. = $\frac{VI}{VI}$+.
O. S. + 0.25 sph. ◯ +1.00 cyl. axis 105°, V. = $\frac{VI}{VI}$+.

April 6: Same result as April 5. Add., 20°. Abd., 6°. Esophoria, 2° at 6 meters.

For Miss Robinson:

℞. O. D. +1.00 cyl. axis 75°.
O. S. +1.00 cyl. axis 105°.

Sig.—For constant use.

April 7: Glasses neutralize; are centered and accurately adjusted.

April 16: Perfectly comfortable. Free from headache since the first day she used the "drops." Add., 20°. Abd., 6°. Esophoria at 6 meters, 2°; and at 13 in., 10° exophoria. Near-point, 12 cm.

Considerations.—Apparently, the static refraction in this case would indicate compound hyperopic astigmatism; but when 0.25 is deducted to produce parallel rays, then the prescription becomes one for simple hyperopic astigmatism.

General Rule for Prescribing Cylinders.—Order the cylinder just as found, without any change in its axis or strength.

The vision in each eye at the different visits, before lenses *were placed* in front of the eyes, was always uncertain, the pa-

tient miscalling certain letters, and hence it is that the vision is recorded with as many question marks as there are mistakes in the line of letters—*i.e.*, $\frac{\text{VI}}{\text{IX}}$???.

In taking the vision at the first visit, the patient could read part of $\frac{\text{VI}}{\text{VIIss}}$ if not closely watched. In other words, if she was permitted to tilt her head to one side and narrow the palpebral fissure by squinting the lids together and making, as it were, a stenopeic slit out of her eyelids, the vision was improved. But when told to open the eye wide, she could read only part of $\frac{\text{VI}}{\text{IX}}$. This is explained by the fact that when the lids were drawn together the vertical meridian was partly excluded, and then, by accommodating, the vision was improved through the horizontal meridian. Astigmatic eyes often take advantage of this condition when the nature of the astigmatism is suitable, but only at the expense of frowning and straining the accommodation.

It will also be noticed that the stenopeic slit was not used as a test at the first visit. This is also explained for the same reason that the patient would draw his lids together and therefore annul the virtue of this test. The stenopeic slit is to be used in these cases only when the ciliary muscle is at rest.

Summary.—When the hyoscyamin has passed out of the eyes and the glasses are in position, the near-point becomes 12 cm., which is quite consistent with the patient's age. Before using drops, the near-point with the eyes wide open was only 13½ cm., representing about 7.50 D.; and this, subtracted from the amplitude for 24 years of age, would leave 1 D. for distance uncorrected.

As every 6 D. cylinder represents 1 mm. of lengthening or shortening of the radius of curvature of the cornea, then this patient, taking a +1 cyl. at axis 75 in the right eye, has the 165° meridian ⅙ mm. too long as compared with the 75 meridian. which is supposed to have the normal radius of 7.8 mm.

The same is true of the meridians of the left eye.

Case IV.—Simple Myopic Astigmatism.—Not a common condition. About 1.5 per cent. of all eyes have this form of refraction.

April 10. Miss Jenks. Age, 18 years. Single.

O. D. V. = $\frac{VI}{X}$???. p. p. 9 cm. p. r. 50 cm.

O. S. V. = $\frac{VI}{X}$???. p. p. 9 cm. p. r. 50 cm.

Add., 20°. Abd., 5°. Esophoria at 6 meters = 3°, and 10° exophoria at 13 in.

Stenopeic Slit.—Axis 90° V. = $\frac{VI}{XXX}$; axis 180 V. = $\frac{VI}{VI}$. Each eye the same.

History.—Never had good distant vision. Has occasional headaches. Comes to find out if glasses will improve vision.

S. P.—Face symmetric. Irises dark in color. Pupils apparently round, 5 mm. in diameter. Eyes out under cover.

Ophthalmometer.—Each eye 2 D., axis 90.

Ophthalmoscope.—O. D., media clear. Disc large and round, with underlying conus out. No physiologic cupping. Choroidal circulation everywhere recognized, characteristic of a stretching eyeball. Horizontal vessels seen with −2; vertical vessels seen without any correcting lens. O. S., same general conditions as in O. D.

Manifest Refraction.—

O. D., −2.50 cyl. axis 180 = $\frac{VI}{VI}$.

O. D., −2.50 cyl. axis 180 = $\frac{VI}{VI}$.

℞. Atropin and dark glasses for refraction.

April 12: 6 meters from test-card and point of light.

O. D. V. = $\frac{VI}{XX}$???.

O. S. V. = $\frac{VI}{XX}$???.

Retinoscopy at 1 meter. Vertical meridian −1.00 S. Horizontal meridian +1.25 S.

Stenopeic slit at axis 180 with +0.25 = $\frac{VI}{VI}$; at axis 90 = *−2.50*, $\frac{VI}{VI}$.

At Trial-case.—

O. D., + 0.25 sph. ○ −2.25 cyl. axis 180° = $\frac{VI}{VI}$.

O. S., + 0.25 sph. ○ −2.25 cyl. axis 180° = $\frac{VI}{VI}$.

April 13: Same results as yesterday. Add. = 20°; Abd. = 6°. Esophoria, 2°.

For Miss Jenks:

℞. O. D., −2.25 cyl. axis 180.
O. S., −2.25 cyl. axis 180.

April 14: Glasses neutralize. Centered and properly adjusted.

April 28: Comfortable. Enjoys good distant vision. Near-point, each eye, 9 cm.

Considerations.—Apparently, the static refraction would indicate mixed astigmatism, but when +0.25 is deducted to produce parallel rays, the prescription resolves itself into one for simple myopic astigmatism.

The general rule for ordering cylinders is the same in myopia as in hyperopia; *i.e.*, no change in the strength or in the axis of the cylinder.

A cycloplegic is always necessary in such cases, as is shown by the different lenses obtained by the manifest refraction and stenopeic slit.

The vision was always uncertain before lenses were placed before the eyes, as is indicated by the question marks.

At the first visit the vision was taken with the eyes wide open. If allowed to narrow the palpebral fissure by squinting the eyelids together and making a stenopeic slit out of them, the patient could read a part of $\frac{VI}{VI?SS}$. When the lids were thus drawn together, the myopic vertical meridian was excluded in part and the horizontal meridian was utilized. The stenopeic slit was of some assistance before drops were used, as the accommodation could not be exerted, as in the case of the hyperope.

Summary.—After recovery from the cycloplegic, small type was clear at 9 cm., which was in keeping with the patient's age. The near-point *before* "drops" were used was also 9 cm., but

not constant, nor was the type clear. The -2.25 cyl. at axis 180 represents about ⅓ mm. of shortening in the vertical radius of curvature as compared with the normal radius of 7.8 mm. in the horizontal.

The astigmatism is regular, symmetric, with the rule.

Case V.—Compound Hyperopic Astigmatism.—The most common form of all refraction. It is a combination of simple hyperopia with simple hyperopic astigmatism. About 44 per cent. of all eyes have this form of refraction.

April 12. Mr. Common. Age, 28. Married. Bookkeeper.

O. D. V. = $\frac{VI}{X}$??. p. p. = type 0.75 D. = 19 cm.

O. S. V. = $\frac{VI}{X}$??. p. p. = type 0.75 D. = 19 cm.

Add., 23°. Abd., 7°. Esophoria, 2°; at 13 in., 10° exophoria.

Astigmatic Clock-dial.—O. D. and O. S. each selects darkest series of lines from XII to VI.

Placido's disc shows each corneal image as a horizontal oval.

Ophthalmometer = 2.25 D. with axis 90 in each eye.

History.—Family physician has tried in vain to stop the headaches, which he said were from biliousness. Headache develops as soon as the patient commences to use his eyes, and gets worse toward noon; and from that time on, during the rest of the day, he is cross and irritable, and feels dizzy. Unable to read in the evenings as he did a few years ago. Is wearing a pair of "rest" glasses, which he received from an optician; they were of some benefit for a very short time.

S. P.—Lid margins red and excoriated. Many fine scales (looking like dandruff) adhering to the cilia. Irises gray in color. Pupils round, 3 mm. Eyes in, under cover.

Ophthalmoscope.—O. D. and O. S. each medium clear. Disc small, vertically oval. Shallow physiologic cup. Venous pulsation on disc. Narrow conus to temporal side. Nerve-head prominent and edges somewhat hazy. No pathologic conditions recognized. Vertical vessels best seen with $+2.00$ and horizontal with $+0.50$.

℞. Duboisin and dark glasses for refraction.

April 14: 6 meters from test-card and point of light.

O. D. V. = $\frac{VI}{LX}$ Doubtful.
O. S. V. = $\frac{VI}{LX}$ Doubtful.

Retinoscopy develops point of reversal at 1 meter in each eye; vertical meridian with +1.75 S., and horizontal meridian with +3.50 S.

Stenopeic slit axis 90° with +1.00 = $\frac{VI}{VI}$; at axis 180° with +2.50 = $\frac{VI}{VI}$.

At Trial-case.—

O. D., +0.75 sph. ⊂ + 1.75 cyl. axis 90 = $\frac{VI}{VI}$.
O. S., +0.75 sph. ⊂ + 1.75 cyl. axis 90 = $\frac{VI}{VI}$.

April 15: Same results as April 14. Add., 22°. Abd., 7°. Esophoria, 1°.

For Mr. Common:
℞. O. D., +0.50 sph. ⊂ +1.75 cyl. axis 90°.
O. S., +0.50 sph. ⊂ +1.75 cyl. axis 90°.
Sig.—For constant use.

April 17: Glasses neutralize; are centered and adjusted.

April 24: Has been perfectly free from headaches ever since getting glasses. Never realized what a blessing glasses could be. Near-point with each eye is now 14 cm.

Considerations.—The prescription for glasses was the same as the static refraction, with the exception of the reduction in the strength of the sphere. No change in the cylinder. A cycloplegic as a means of obtaining a prompt, correct, and satisfactory correction in such cases cannot be dispensed with.

The decided change in the vision before and with the cycloplegic is quite diagnostic of compound hyperopic astigmatism. When the cylinder and sphere are of any considerable strength, the patient can often overcome (facultative hyperopia) the spheric, but not all of the cylindric. error.

Summary.—After recovery from the cycloplegic the small type becomes clear at about 13 cm., which is the near-point consistent with the patient's age. The far-point before using drops was really two points, both negative—that of the vertical meridian being about 2 meters, and the horizontal meridian about ½ meter, back of the retina.

The form of the astigmatism is regular, symmetric, and with the rule.

Case VI.—Compound Myopic Astigmatism.—A combination of simple myopia with simple myopic astigmatism. This is the usual form of refraction in myopic eyes. About 8 per cent. of all eyes have compound myopia. The writer's experience is such that he never refracts a case of myopia without searching carefully for a cylinder in combination with the sphere (see page 330).

April 12. MRS. USUAL. Age, 30 years. Married. Housewife.

O. D. V., $\frac{VI}{L}$?, type 0.50 = 10 to 33 cm.

O. S. V., $\frac{VI}{L}$?, type 0.50 = 10 to 33 cm.

Add., 16°. Abd., 6°. Exophoria at 6 meters, 2°.

History.—Suffers from ocular pains, as if knife-points were sticking into the eyes, which come on as soon as near-work is attempted or continued. Says that she constantly sees fine dust particles floating before her vision. Has been wearing glasses from an optician (−3 sph.). Has all the symptoms of near-sightedness. Family history: her father and two sisters wearing glasses for "near-sight."

S. P.—Face symmetric. Eyeballs prominent. Irises dark in color. Pupils small (for a myope) and round, 3 mm. Eyes markedly out under cover.

Ophthalmoscope.—O. D., many fine floating vitreous opacities. Nerve large and round, with broad underlying conus down and out. Choroidal vessels seen throughout eye-ground. Vessels at axis 120° best seen with −2, and vessels at axis 30° best seen with −3. O. S., same general conditions as in O. D., *except the* principal meridians are about 60° and 150°.

Indirect method shows a vertically oval nerve, with the conus to the nasal side of the aerial image (as the eye-ground and nerve-head have undergone vertical and lateral inversion). Withdrawing the lens, the nerve grows larger in all meridians, but more so in the vertical.

Stenopeic slit before O. D. at axis 120 V. = $\frac{VI}{LX}$; at axis 30 V. = $\frac{VI}{XX}$??. O. S., the same with axis 60° and 150°.

Astigmatic Chart.—O. D. selects the lines from V to XI as darkest. O. S. selects the lines from VII to I as darkest.

Ophthalmometer.—O. D., 1 D., axis 35°. O. S., 1 D., axis 145°.

Manifest.—

O. D., −2.50 sph. ⊂ −0.75 cyl. axis 35 = $\frac{VI}{VII}$????.
O. S., −2.50 sph. ⊂ −0.75 cyl. axis 145 = $\frac{VI}{VII}$????.
℞. Atropin and dark glasses for rest and refraction.

April 13: At 6 meters from test-card and point of light:

O. D. V. = $\frac{VI}{LX}$ +. O. S. V. = $\frac{VI}{LX}$ +.
O. D., −2.00 sph. ⊂ −1.00 cyl. axis 30 = $\frac{VI}{VI}$.
O. S., −2.00 sph. ⊂ −1.00 cyl. axis 150 = $\frac{VI}{VI}$.

Retinoscope confirms this trial-case finding. Retinsocope also shows a general cloudiness of the media (vitreous), which, of course, will account in part for the vision not being $\frac{VI}{V}$ in each eye with correcting glasses.

April 14: Same result as on the 13.

For Mrs. Usual:

℞. O. D., −2.00 sph. ⊂ −1.00 cyl. axis 30°.
O. S., −2.00 sph. ⊂ −1.00 cyl. axis 150°.

Sig.—For distance, as directed.

April 15:

℞. Tonics. Rest of eyes. Attention to general health.

April 17: Glasses neutralize; are centered and adjusted.

April 29: Add., 16°. Abd., 6°. Exophoria, 2°.

Vision in each eye $\frac{VI}{VI}$, read slowly.

Considerations.—The static refraction was ordered just as found, and no deduction whatever was made in the sphere. The rule is to prescribe in the same way as in simple myopia. But all cases of myopia cannot and must not be prescribed for by rule. Each case of myopia is a law unto itself. See description under General Considerations, page 321, also pages 322, 323, and 324.

Summary.—The near point is now 14 cm., which is perfectly consistent with the patient's age. Fourteen cm. represent an accommodative power of 7 D., and this was the difference between the near and far points before the drops were used. The astigmatism is regular, symmetric, and with the rule. Vision is not brought up to normal on account of the changes in the vitreous and disturbed eye-ground, due, no doubt, to the want of a proper correction—the cylinder. The choroid and retina are both in a stretching condition.

Case VII.—Mixed Astigmatism.—Not an uncommon condition. About 6½ per cent. of all eyes have this form of refraction. This is a combination of the simple hyperopic and simple myopic astigmatisms, with their axes opposite or at right angles to each other, as a rule.

April 8. Mr. Crook. Age, 21 years. Single. Clerk.

O. D. V. = $\frac{VI}{XL}$. p. p. = 12 cm. with type 0.75 D.
O. S. V. = $\frac{VI}{XL}$. p. p. = 12 cm. with type 0.75 D.
Add., 20°. Abd., 10°.

History of poor sight all his life, but thinks it was better as a boy. Has frequent frontotemporal headaches, which are worse after using eyes at any prolonged near-work. Father has good sight, but his mother and her family have all been near-sighted; has one aunt that developed cataracts. Has been to several "stores," but could not get fitted with glasses that would improve his vision.

S. P.—Face broad and symmetric. Long interpupillary *distance.* Irises dark in color. Pupils large, 5 mm.; round. *Eyes out* under cover.

Ophthalmoscope.—O. D., media clear. Disc vertically oval, axis 105. Macular region shows changes. Vessels at 105 best seen with +2, and at right angles with −2. O. S., same conditions found, except that the meridians are at 75° and 165°.

Ophthalmometer.—O. D., 4 D. axis 100. O. S., 4 D. axis 75.

Stenopeic Slit.—O. D. axis 15 with +2 sph., V. = $\frac{\text{VI}}{\text{X}}$; at axis 105 with −2 sph., V. = $\frac{\text{VI}}{\text{IX}}$. O. S. axis 165 with +2 sph., V. = $\frac{\text{IV}}{\text{IX}}$; at axis 75 with −2 sph., V. = $\frac{\text{VI}}{\text{X}}$.

Indirect Method.—Each disc in the aerial image shows a lengthening of the vertical meridian as the condensing lens is withdrawn from the eye, and at the same time the horizontal meridian grows narrower. As the lens is advanced toward the eye the vertical meridian grows shorter and the horizontal meridian grows broader.

The astigmatic chart does not show any difference in the shading of the lines; they all appear equally indistinct. Retinoscope at 1 meter distance shows myopia in the vertical meridian and hyperopia in the horizontal.

℞. Atropin and dark glasses for refraction.

April 10: At 6 meters from test-card and point of light. O. D. and O. S. V. = $\frac{\text{VI}}{\text{LX}}$.

Retinoscope at the distance of 1 meter shows point of reversal in O. D. at axis 105° with −1.50 D., and axis 15 with +3 D. O. S., axis 75 with −1.50 D., and axis 165 with +3 D.

Stenopeic Slit.—O. D., axis 15 with +2 sph., V. = $\frac{\text{VI}}{\text{IX}}$; axis 105 with −2.50 sph., V. = $\frac{\text{VI}}{\text{IX}}$. O. S., axis 165 with +2 sph., V. = $\frac{\text{VI}}{\text{IX}}$; at axis 75 with −2.50 sph., V. = $\frac{\text{VI}}{\text{IX}}$.

At Trial-case.—O. D., −2.50 cyl. axis 15° $\bigcirc$ + 2 cyl. axis 105°, V. = $\frac{\text{VI}}{\text{VIISS}}$. O. S., − 2.50 cyl. axis 165 $\bigcirc$ + 2 cyl. axis 75, V. = $\frac{\text{VI}}{\text{VIISS}}$.

Or,

O. D., −2.50 sph. $\bigcirc$ +4.50 cyl. axis 105 V. = $\frac{\text{VI}}{\text{VIISS}}$.
O. S., −2.50 sph. $\bigcirc$ +4.50 cyl. axis 75, V. = $\frac{\text{VI}}{\text{VIISS}}$.

Or,

O. D., +2 sph. ⌾ −4.50 cyl. axis 15°, V. = $\frac{VI}{VIISS}$+.
O. S., +2 sph. ⌾ −4.50 cyl. axis 165°, V. = $\frac{VI}{VIISS}$+.

April 11: Same results as April 10. Add., 20°. Abd., 8°.

For Mr. Crook:

℞. O. D., +1.75 sph. ⌾ −4.50 cyl. axis 15°.
O. S., +1.75 sph. ⌾ −4.50 cyl. axs 165°.

Sig.—For constant use.

April 12: Glasses neutralize; are centered and adjusted.

April 26: Near-point 10 cm., which is consistent with age of patient.

Considerations.—The ophthalmoscope, retinoscope, blue glass, indirect method, and stenopeic slit were direct guides to the character of the refractive error. Emphasis is placed upon these different methods, as so many beginners in ophthalmology have a fear or dread of making mistakes in refracting cases of mixed astigmatism.

The *stenopeic slit* shows a difference of 4.50 in the two principal meridians; bearing this fact in mind, if a −4.50 cyl. at axis 15 be placed before the right eye, then all meridians would be made equally hyperopic 2 D. Combining +2 sph. with the −4.50 cyl. at axis 15 in the right eye or at axis 165 in the left, the refraction would be corrected.

Or if a +4.50 cyl. at axis 105 be placed before the right eye, then all meridians would be made myopic 2.50 D. Combining a −2.50 sph. with this +4.50 cyl. at axis 105 in the right eye or at axis 75 in the left eye, the refraction would be corrected.

For a further consideration of combination of lenses see page 76.

The rule for ordering cylinders is the same in mixed astigmatism as in other cylindric corrections—without change.

Summary.—The character of the astigmatism is regular, *symmetric,* and with the rule. The near-point returns to the

normal for the age. Eyes with such high errors do not, as a rule, obtain a visual acuity of $\frac{VI}{VI}$, for the reason that changes have taken place in the eye-ground, especially at the macula.

Case VIII.—Irregular Astigmatism.—

April 2. Mary Smiles. Age, 10 years.
O. D. V. = $\frac{VI}{XXX}$ slowly. No p. p. obtained.
O. S. V. = $\frac{VI}{LX}$. Doubtful. No p. p. obtained.

History of poor sight ever since an attack of measles when two years of age, at which time was kept in a dark room for six weeks. Eyes were never strong afterward; always very sensitive to light. Child was sent home from school with a note from the teacher: "Mary is near-sighted and should see a doctor."

S. P.—Eyelids appear normal. Excessive epiphora. Corneas nebulated, especially O. S., which has a decided leucoma at the pole. Anterior chambers of normal depth. Pupils 3 mm., round. Corneal reflex very irregular.

Ophthalmoscope.—No view obtained of the eye-ground through the small pupils on account of corneal opacities. Homatropin mydriasis shows O. D. cornea faintly nebulated in scattered areas; rest of media clear. Nerve small and round. Vessels at axis 35° best seen with +2 D. O. S.; there is a 3-mm. area of opacity at the pole of the cornea; no clear view of the eye-ground. Indirect method shows a small nerve and refraction hyperopic.

℞. Atropin and dark glasses for refraction.

April 22: Retinoscope at 1 meter shows band of light at axis, 35, indicating hyperopia. Other meridians very irregular. O. S., nothing definite made out.

Placido's disc shows irregular, distorted circles.

With Pin-hole Disc.—O. D. V. = $\frac{VI}{XX}$. O. S. V. = $\frac{VI}{LX}$.

With Stenopeic Slit.—Axis 45° before O. D. and with + 2.25 S., V. = $\frac{VI}{XV}$??. O. S., cannot improve vision with any glass.

At Trial-case.—O. D. +2.00 cyl., axis 45 = $\frac{VI}{XV}$??. O. S., no glass accepted.

April 23: At trial-case O. D., +1.75 cyl. axis 35 = $\frac{VI}{XV}$.

For Mary Smiles:

℞. O. D., – 0.25 sph. ⊃ + 1.75 cyl. axis 35°.
O. S., plane glass.

Sig.—Constant use.

Considerations.—This case shows the advantage of the stenopeic slit and the use of the pin-hole disc. The near point could not be obtained on account of the poor qualities and the child's inability to appreciate what was wanted.

Case IX.—Tonic Cramp or Spasm of the Accommodation.—

Mrs. L. Age, 24 years.

O. D. V. = $\frac{VI}{XL}$??. p.p. = 9 cm. (?) Add., 24°. Abd., 6°. Esophoria, 4°.
O. S. V. = $\frac{VI}{XL}$??. p.p. = 9 cm. (?) No vertical deviation.

History of having had glasses changed on three different occasions during the past year. Drops were used each time, and the three prescriptions were all different. Glasses were always satisfactory for the first week, but after this time she was always able to see better at a distance without them. Has pains in her eyes and all over the head whenever she attempts to use the eyes with or without any glasses. Headaches nearly set her "wild" if she tries to concentrate her vision on a distant or near object. Has not been able to read or write or sew for the past two years. Has been under the care of the gynecologist and neurologist, and they each pronounce her physical condition as normal. The neurologist suggests a diagnosis of "hysteria." Patient sleeps well and has a good appetite, but will suffer from nausea and vomiting if she uses her eyes for any length of time. Patient has been married five years. Has one living child. No miscarriages. Is apparently in the very best of health, and is provoked with her apparent good health as not being consistent with her suffering, and hence she does not receive any sympathy from her family or her friends.

S. P.—No external manifestations of any ocular irregularity.

Manifest Refraction.—

O. D., -0.50 S. $\bigcirc$ $+1.00$ cyl. axis 90° = $\frac{VI}{VI}$.
O. S., the same as O. D.

Ophthalmoscope.—O. D. and O. S. media clear. Discs vertically oval, eye-grounds "woolly." Accommodation very active. Shot silk retina. Refraction is compound hyperopic astigmatism.

℞. Atropin and dark glasses for refraction.

Static Refraction.—

O. D. $+1.50$ S. = $+1.75$ cyl. axis 90° = $\frac{VI}{VI}$.
O. S. $+1.50$ S. = $+1.75$ cyl. axis 90° = $\frac{VI}{V}$.

Patient states that her "pains and headaches all disappeared after using the drops for the third time."

Refraction repeated on three different occasions, and the following prescription given:

For Mrs. L.

℞. O. D., $+1.25$ S $\bigcirc$ $+1.75$ cyl. axis 90°.
O. S., $+1.25$ S. $\bigcirc$ $+1.75$ cyl. axis 90°.

Glasses properly centered, and accurately adjusted.

After ten days patient returns with the statement that her pains and aches have recurred as before, and that she can see better at a distance without her glasses. With correction, each eye sees $\frac{VI}{XL}$, and with both eyes can see $\frac{VI}{XXX}$. Add., 20°, and abd., 8°. No vertical deviation. Has 3° esophoria at 6 meters.

℞. Atropin $\frac{1}{20}$ of a grain to the ounce.
Sig.—To use one drop in each eye each morning and noon.

To wear a pair of dark glasses with her prescription glasses when exposed to any bright light. Not to attempt any near-work. This treatment was continued, off and on, for six months. Patient was always free from ocular pain and head-

ache as long as the atropin was being used, but as soon as the ciliary muscle commenced to contract, then the pains would return with all their former severity. This patient eventually recovered by using her distant correction with a pair of +2 spheres as hook-fronts for any near-work.

Case X.—Exophoria.—

Miss V. B. D. Age, 22 years.

O. D. V. = $\frac{VI}{VI}$. p. p. = 0.50 D., type at 11 cm.

O. S. V. = $\frac{VI}{VI}$. p. p. = 0.50 D., type at 11 cm.

Add. and abd., 12°. Exophoria, 4°.

History of seeing double several times a day. Says she sees her nose at times. Friends and members of her family have told her she was "squinting." Always returns home with a severe occipital headache after going shopping or to any place of amusement. Has headache when using her eyes, but it soon passes away after resting the eyes.

S. P.—Eyes markedly out under cover. Irises react promptly to light, accommodation, and convergence. Fixation test shows the right eye divergent.

Ophthalmoscope.—O. D. and O. S. No apparent changes, and refraction almost emmetropic; some small amount of hyperopia and astigmatism.

℞. Atropin and dark glasses for rest and careful refraction.

Static refraction, after several repetitions, O. D. and O. S., +0.50 S. ⊃ +0.37 cyl. axis 90° = $\frac{VI}{V}$. And this is ordered, less 0.50.

With this correction carefully centered, add. = 14° and abd. = 12°, with 3° of exophoria at 6 meters and 15° of exophoria at 13 in. This patient was given prism exercises for more than two months, and, finally after the adduction reached 30° and abduction was 10° and 3° of esophoria were obtained, the prism exercises were stopped, and patient told to report promptly if any discomfort arose at any time. To wear her glasses con-

stantly. At the present (1910) time this patient would receive the fixation exercise and not the long treatment with prisms.

Case XI.—Anisometropia.—

MR. ALBERT S. Age 29 years. In general business.

O. D. V. = $\frac{VI}{XXX}$. p. p. type 0.50 D. = 25 cm.
O. S. V. = $\frac{VI}{XL}$. p. p. type 0.75 D = 30 cm.
Add., 10°. Abd., 6°. Left Hy., 2°.

History.—Has had three pairs of glasses ordered, with "drops," during the past 18 months. Has never had any but the very slightest relief from ocular pains and frontal headaches, which have been almost constant for the past four years or more. On account of the ocular discomfort and headaches, the patient has given up all attempts to read for more than 15 minutes at a time. Patient states that if he uses his eyes for more than this length of time they become bloodshot and very tender to the touch. General health of patient is excellent; has a good appetite and sleeps well. Does not use tobacco or liquor of any kind.

S. P.—Face symmetric. Nose very prominent. Interpupillary distance, 62 mm.

Ophthalmoscope.—O. D., nerve-head over capillary. Not swollen. Accommodation very active. Eye-ground "fluffy." Refraction is that of compound hyperopia. O. S., same general conditions, but the nerve is vertically oval and the refraction is compound hyperopic astigmatism.

℞. Atropin and dark glasses for refraction.

Static Refraction.—

O. D., +2.00 S. ○ +1.00 cyl. axis 75° = $\frac{VI}{VI}$ ⎫ 2 Δ of left hyper-
O. S., +1.25 S. ○ +3.00 cyl. axis 105° = $\frac{VI}{VI}$??? ⎭ phoria.

℞. O. D., +1.75 S. ○ +1.00 cyl. axis 75° ○ $\frac{3}{4}$ Δ base up.
O. S., +1.00 S. ○ +3.00 cyl. axis 105° ○ $\frac{3}{4}$ Δ base down.

SIG.—For constant use.

This patient was not made comfortable until he was given 5-grain doses of the bromid of potash three times a day for four weeks. Is now able to use his eyes without the least *discomfort.*

CHAPTER XX

THE VISUAL ACUITY UNDER DEFINITE CONDITIONS IS AN INDEX OF THE STRENGTH OF THE NECESSARY SPHERIC LENS (PLUS OR MINUS) WHICH WILL GIVE A VISION OF $\frac{VI}{VI}$ OR MORE[1]

For several years the writer has been making a careful examination of his private cases for the purpose of coming to the positive and demonstrable fact as above stated. For instance, the question which has been decided is this: if a healthy eye, hyperopic or myopic, without astigmatism (or an eye with its astigmatism corrected with a cylinder), and it has the ability to see $\frac{VI}{VI}$ and its ciliary muscle under the effect of "drops," what strength spheric lens would be required to give it normal vision?

For purposes of study the eyes selected were those which obtained standard or more than standard vision with correcting lenses, and all eyes which from any cause could not attain at least $\frac{VI}{VI}$ vision were excluded from the tests and are not a part of the subject-matter under consideration. To make these tests reliable two essentials were absolutely necessary: namely, the ability to read $\frac{VI}{VI}$ or more and the ciliary muscle under the effect of a reliable cycloplegic.

To begin with, the writer had to work backward, so to speak, and in the following manner: the eyes were tested at 6 meters, and *with* the lenses which gave standard vision, the eyes were tested to find out what their visual acuities would be when plus spheres were placed in front of the correcting lenses. The

[1] This paper was read before the Ophthalmic Section of the College of Physicians of Philadelphia, Dec. 17, 1908.

spheric lenses used ranged from +0.25 to +2.50 in quarter diopter intervals. The resulting visions obtained are shown in the following table.

Static refraction with correcting lenses....................	Vision =	$\frac{\text{VI}}{\text{VI}}$
Static refraction with correcting lenses adding + 0.25.......	Vision =	$\frac{\text{VI}}{\text{VII}}$
Static refraction with correcting lenses adding + 0.50.......	Vision =	$\frac{\text{VI}}{\text{VIISS}}$
Static refraction with correcting lenses adding + 0.75.......	Vision =	$\frac{\text{VI}}{\text{VIIISS}}$
Static refraction with correcting lenses adding + 1.00.......	Vision =	$\frac{\text{VI}}{\text{X}}$
Static refraction with correcting lenses adding + 1.25.......	Vision =	$\frac{\text{VI}}{\text{XII}}$
Static refraction with correcting lenses adding + 1.50.......	Vision =	$\frac{\text{VI}}{\text{XV}}$
Static refraction with correcting lenses adding + 1.75.......	Vision =	$\frac{\text{VI}}{\text{XX}}$
Static refraction with correcting lenses adding + 2.00.......	Vision =	$\frac{\text{VI}}{\text{XXX}}$
Static refraction with correcting lenses adding + 2.25.......	Vision =	$\frac{\text{VI}}{\text{LX}}$

With +2.50 added the vision was less than $\frac{\text{VI}}{\text{LX}}$.

Studying the table in reverse order it was then found that all healthy eyes, hyperopic or myopic (or eyes with the astigmatism corrected), and under the effect of "drops" required a spheric lens (plus or minus as the case might be) consistent with the visual acuity as given in this table. The interesting fact was also apparent that a +2.50 spheric lens reduced the vision so that the "LX" letter *could not* be distinguished, thus the 2.50 obscured the vision to zero as the eye could not detect ***any*** letter at 6 meters. It therefore became evident that an eye with the two essential conditions mentioned, and having a vision of more than $\frac{\text{VI}}{\text{LX}}$, would require a spheric lens of less strength than 2.25, and if its vision was less than $\frac{\text{VI}}{\text{LX}}$ it would require a spheric lens of 2.50 or stronger.

To meet the visual conditions shown in Table 1, the author had made a series of letters on duplicate cards, and for obvious reasons called them "Metric Test Letters." These letters conform to the tangent of the angle of 5′ and of the Gothic character in preference to the English block letters. These letters are arranged in series to be seen at the various distances as indicated in meters and the equivalent in feet. The confusion

letters are conspicuous and the two cards have corresponding letters on the same lines but differently arranged. These cards also differ from the cards in ordinary use, as there is a line of letters to be seen at VI⅔ meters and also at VIIISS meters; the XXV meter line as seen on other cards has purposely been omitted. The question is often asked why test-types are not arranged so as to give a visual acuity at 55, 50, 45, and 40

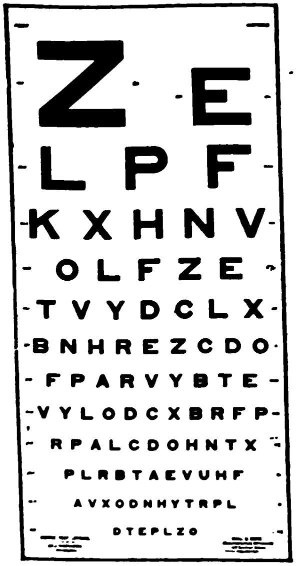


FIG. 294.

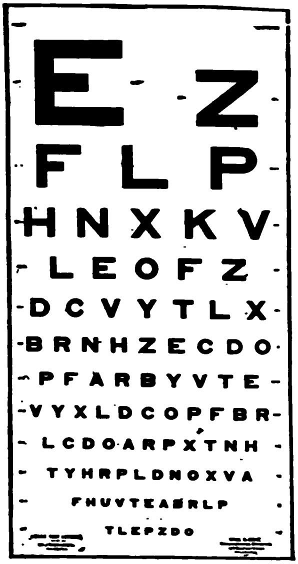


FIG. 295.

meters, but the uselessness of such letters is easily understood by a review of the visual acuities just tabulated. The writer has, however, placed one letter on each of the cards here shown (Figs. 294 and 295), which letters can be seen at 40 meters, but these are not a part of the test here described, but will be found convenient in an office with a 4-meter range. It will be seen from the following table that by the arrangement of the size of the letters the visual acuity can always be reduced to tenths as follows:

TABLE 2

Vision	$\frac{\text{VI}}{\text{LX}}$	equals	1/10
Vision	$\frac{\text{VI}}{\text{XXX}}$	equals	2/10
Vision	$\frac{\text{VI}}{\text{XX}}$	equals	3/10
Vision	$\frac{\text{VI}}{\text{XV}}$	equals	4/10
Vision	$\frac{\text{VI}}{\text{XII}}$	equals	5/10
Vision	$\frac{\text{VI}}{\text{X}}$	equals	6/10
Vision	$\frac{\text{VI}}{\text{VIIISS}}$	equals	7/10
Vision	$\frac{\text{VI}}{\text{VIISS}}$	equals	8/10
Vision	$\frac{\text{VI}}{\text{VI⅔}}$	equals	9/10
Vision	$\frac{\text{VI}}{\text{VI}}$	equals	10/10

As the visual acuity is now reducible to tenths it becomes a rule of thumb, so to speak, to calculate the strength of the correcting spheric lens necessary to produce normal or standard vision when it is remembered that +2.50 just reduces the vision of a standard or emmetropic eye to zero, or that +2.25 gives 1/10 vision. Take, for instance, a vision of 1/10; that means that the eye is deficient 9/10 or requires 9/10 additional to give it 10/10 or standard sight. As 1/10 of 2.50 is 0.25, then nine times 0.25 would be 2.25, the amount of spheric lens required. Or if an eye sees the xxx meter letters it has 2/10 vision and requires 8/10 additional to give it 10/10 or normal vision, namely, eight times 1/10 of 2.50, which is 2.00 (plus or minus). If the vision is 4/10, the eye would require 6/10 more, or 1.50, to give it standard vision. The following table, which includes the two just given, shows the strength of the spheric lens required in each instance when the visual acuity is expressed in tenths. By his previous ophthalmoscopic findings and with his retinoscope, and obtaining the patient's near-point, etc., the observer will know when to employ a plus or a minus spheric lens.

To make the metric test-letters of value when the eyes are astigmatic, it will be necessary to correct the astigmatism with the necessary cylinder *before* testing the visual acuity. For this purpose the writer has also prepared metric lines in the form of the clock-dial (Fig. 296). This dial has been made in two

TABLE 3

English feet	Meters	Vision at 6 meters	Vision in tenths	Spheric lens required for $\frac{VI}{VI}$ vision
197.0	lx	$\frac{VI}{LX}$	$\frac{1}{10}$	2.25
98.5	xxx	$\frac{VI}{XXX}$	$\frac{2}{10}$	2.00
65.6	xx	$\frac{VI}{XX}$	$\frac{3}{10}$	1.75
49.2	xv	$\frac{VI}{XV}$	$\frac{4}{10}$	1.50
39.4	xii	$\frac{VI}{XII}$	$\frac{5}{10}$	1.25
32.8	x	$\frac{VI}{X}$	$\frac{6}{10}$	1.00
27.9	viiiss	$\frac{VI}{VIIISS}$	$\frac{7}{10}$	0.75
24.6	viiss	$\frac{VI}{VIISS}$	$\frac{8}{10}$	0.50
21.8	vi$\frac{2}{3}$	$\frac{VI}{VI\frac{2}{3}}$	$\frac{9}{10}$	0.25
19.7	vi	$\frac{VI}{VI}$	$\frac{10}{10}$	0.00
16.4	v	$\frac{VI}{V}$	$\frac{12}{10}$	0.00
13.9	iv$\frac{1}{4}$	$\frac{VI}{IV\frac{1}{4}}$	$\frac{14}{10}$	0.00

sizes, one for 5 and the other for a 6-meter distance. These charts vary somewhat from the ordinary in that the lines from xii to vi and from ix to iii cross each other at the center. And also the Roman characters conform to the tangent of the angle of 5′, as do the lines and spaces. While using these charts it will be well to ask the patient whether the Roman characters correspond with the lines in their shade of black. As a matter of practical experience the writer is partial to just such lines and spaces as here described, notwithstanding the fact that others recommend wider lines and spaces. In using the metric letters and lines the writer follows the method recommended by Dr. J. S. Johnson, of St. Paul, and described in the "Ophthalmic Record," Oct., 1901; that is to say, to correct the astigmatism with the cylinder as the patient looks at the lines, and when they all appear equally black (not necessarily distinct) then the visual acuity is taken and the necessary spheric lens employed as indicated in the above table.

To expedite matters and have the patient read the lowest line of letters which he can see without naming the letters from

the top of the card, the writer makes use of the red and green strips of paper suggested by Dr. Holbrook Lowell, of Boston, in his description published in the "Archives of Ophthalmology," Vol. xxxv, No. 5, 1906.

In tabulating the strength of lenses which all patients select, it is found to be an interesting fact that about 86 per cent. of all patients coming for correcting lenses, select a lens not stronger than a 4-diopter sphere or cylinder or both in one or both eyes, so that this 86 per cent. could be successfully refracted with a limited number of lenses in the triăl-case; but the point which is still more interesting is, that nearly 70 of this 86 per cent. accept lenses of less than 2.50 and obtain a vision of $\frac{VI}{VI}$ or more in one or both eyes. With these facts in mind the value of the metric test-letters and lines is self-evident. This quick method of arriving at the correct lenses may not appeal to the slow ophthalmologist who criticises "quick work as poor work," but in clinical work at least the assistant has a time-saver which he will enjoy. However, when by this method the vision has been brought to normal, the ophthalmologist should not prescribe until he has verified the correction by trying the various weaker spheres and cylinders as described on page 314. At this final testing the examiner should use the twelve one-hundredths lenses, as no provision has been made in the metric letters for a visual acuity in fractions of less than one-tenth, as this would have necessitated additional lines of letters and a much larger card.

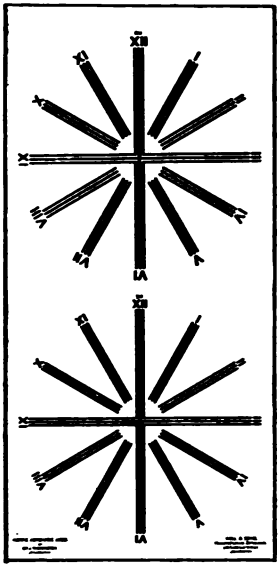


FIG. 296.

The metric letters and lines may be used when practising

the "fogging method," but as most eyes do not entirely relax the ciliary muscle when so tested, the visual acuity is liable to be one-tenth or sometimes two-tenths more than it would be if the eye was under the effect of "drops."

In presbyopic cases the metric letters prove very satisfactory if there are no structural changes to interfere with normal vision. To summarize:

1. The eye which is being tested, unless decidedly presbyopic, should have its ciliary muscle at rest with a reliable cycloplegic.

2. The eye *must* be capable of obtaining $\frac{VI}{VI}$ vision or more than $\frac{VI}{VI}$.

3. All testing must be done at a distance of 6 meters.

4. If the eye is astigmatic this must be corrected with the necessary cylinder lens before taking the visual acuity and adding the spheric lens.

5. The visual acuity obtained if the eye is hypermetropic or myopic (or astigmatism corrected) is an index of the strength of the spheric lens required to give $\frac{VI}{VI}$ vision.

6. The same lens or lenses which give a vision of $\frac{VI}{VI}$ will at times give a vision of more than $\frac{VI}{VI}$, and without any change if the lenses have been carefully selected and the eye is capable of seeing more than $\frac{VI}{VI}$.

7. This metric letter testing is of advantage in proving the static correction, as shown in Table 1.

CHAPTER XXI

RETINOSCOPY AND FOGGING METHOD COMBINED

This may be called dynamic retinoscopy and is described as retinoscopy without the use of a cycloplegic combined with the fogging method. In this application of retinoscopy (see page 188), most of the arrangements are carried out as described in Chapter XI.

The Room.—This is moderately darkened and no light from any direct source is permitted to enter either eye of the patient.

The patient should be comfortably seated and told to direct his vision across the room at some definite small object, such as a door knob, small vase on a table or a small card hung on the wall, but whatever the small object may be, it should be as nearly as possible on the horizontal line of vision so that the patient's vision will not be directed upward or downward.

The light and asbestos cover-chimney are to be placed on the same horizontal line of vision but slightly back of the patient's head and on the side corresponding to the eye to be refracted; the light from the 1-cm. opening in the chimney must not be allowed to fall on or into the eye under observation, but this same light may fall upon the patient's ear and cheek (see Fig. 158).

The observer should sit while making the test and at the side of the patient corresponding to the eye under observation. He may work as close as 10 in. or as far away as 2 meters, in fact he may vary this distance from time to time as he proceeds with the test. The observer may accommodate freely and does not have to make any note of this whatever.

Patient's Accommodation.—It is the observer's duty to do all he can in every way possible to keep the patient from accom-

modating; this is the purpose of having the patient look into infinity or across a long room, the greater the distance the better. All eyes that are hyperopic will naturally accommodate as they look at the distant object but they will not accommodate as much as they would if the vision was directed to a closer object. Eyes that approximate the emmetropic state will not be called upon to do much accommodating when looking at this long distance. The less the accommodative effort the less the pupillary contraction and naturally the observer wishes to have the pupil as wide open as possible. The placing of prisms (2 or 3 prism diopters) bases in before the eyes, with the idea that they prevent accommodative effort by relaxing convergence as the patient looks at the fixing object, does not appeal favor-

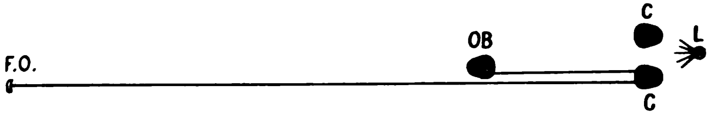


FIG. 297.—C.C. are two chairs for use of the patient. OB is chair for the observer. L is the light in cover-chimney. Two dots represent the patient's eyes on the chair to the left, looking at the fixing object (F.O.). Two dots on the observer's chair represent the observer's eyes looking into the patient's right eye. The patient's left eye alone sees the F.O. as the observer's head purposely obstructs the view of the patient's right eye. If patient were seated on the other chair, the observer's head would obstruct the view of the patient's left eye.

ably to the writer's personal experience along these lines as in any way accomplishing the purpose intended; on the contrary, the prisms interfere and are annoying in many ways and especially by reflecting the light as if a small mirror was before the patient's eye.

Position of Patient, Light, Fixing Object and Observer.—These must be on a straight line, the observer and light being to the right of the patient when examining the right eye and to the left when examining the left eye (see Fig. 297). The writer places two chairs for the patient's use, about 1 ft. apart and between them is placed the light about 44 or 45 in. from the floor. The observer takes his place in front of the light about

54 in. away. The patient's eye being about 14 in. in front of the light and to one side; this makes the observer's and patient's eyes 1 meter apart when making the first observation. The fixation object is placed across the room directly back of the observer, so that the light, observer and fixing object are in a straight line. From a careful study of Fig. 297 it will be noted that the observer's head is just in line with the patient's eye under observation, which is directed to the fixing object, the purpose being to get the patient's and observer's vision in the same line exactly. The patient's other eye is seeing the fixing object and unless the patient closes his fixing eye he does not realize that the eye the observer is examining is not seeing the object. In cases of squint this unique arrangement cannot be so conveniently executed and the observer must move his head a little to one side so as not to obstruct the patient's view. In cases of squint it is necessary to cover the eye that is not being refracted. It is an interesting fact that when the first attempt is made to get the "reflex," the patient's pupil immediately contracts and no very definite idea of the refraction is obtained, but just as soon as the patient becomes comfortable and understands what is expected of him, he fixes the object, so to speak, the pupils dilate and the observer has no further trouble to obtain the fundus reflex as long as the patient remains obedient to instruction to "watch the object."

With these details carefully executed, the observer is now ready to make a note of his findings just as he would proceed if the patient's eyes were under the effect of a cycloplegic and the patient's vision directed to the letters on the metal disc of the retinoscope. The observer makes a rapid mental notation as to the appearance of the pupillary reflex, whether the illumination appears stationary or moves against or with the movement of the mirror and whether this movement appears to move fast or slowly, if there is a band of light present, the meridian it occupies and also if there are any opacities in the media.

With these facts detailed from this first observation the

observer is ready to place the trial-frame and any preliminary lens before the eye. If there is no movement of the illumination at the 1-meter distance, the observer appreciates the fact that the eye is myopic 1 diopter and he is working now at the point of reversal. If the illumination moves with and rapidly, and +1 diopter sphere stops all movement, then the refraction of that eye is emmetropic. If the movement is against and rather fast and a −1 diopter sphere stops all movement, the observer knows that the refraction of that eye is myopic 2 diopters, the observer keeping his distance of 1 meter from the eye. If the illumination appears to move with and slowly, and a +4 diopter sphere stops all movement, then the refraction of that eye is hyperopic 3 diopters. It becomes more and more evident to the observer as he uses plus lenses before the eye of the patient, that an enlargement of the pupillary area is obtained and how easy the retinoscopy test becomes under these conditions. The presence of a band of light and the meridian which it subtends, either before or after placing a spheric lens before the eye, makes the study of the astigmatic error entertaining, to say the least, and it certainly inspires confidence in the observer as he later on turns from the retinoscope to the trial-case to confirm his findings and places the cylinder lens before the eye at the correct axis. When the band of light has been thus detected with the retinoscope, the observer places the cylinder lens before the eye and increases or decreases its strength until he obtains the point of reversal in the meridian opposite to the meridian of the axis of the band of light; for instance, if the band of light were in the meridian of axis 90 (see page 224), and moves with the movement of the mirror in the 180 meridian (horizontal) and a +2 cyl. placed at axis 90° stops all movement in the 180 meridian, the observer knows that the +2 cyl. axis 90 is the correct lens at this distance of 1 meter at which he was working or holding the mirror.

Whatever the retinoscopic findings may be at the distance at which the observer found them, no matter whether it was at 1

meter, or 2 meters or 1/3 meter, it makes no difference, this correction, whatever it may be, is placed before the patient's eye as he looks at the card of test-letters at 20 ft. or at whatever distance the observer is accustomed to do his refraction work. This retinoscopic correction will always be a myopic correction or a "fogging" correction and the patient cannot see the lower letters on the test-card clearly. From now on the fogging method comes into use and all the observer has to do is to add minus spheres to the correction in the trial-frame; this addition of minus spheres must be done slowly and beginning with -0.25, to change to each succeeding number stronger (-0.37, -0.50, -0.62, etc.) until the visual acuity is brought to the $\frac{VI}{VI}$ line or $\frac{VI}{V}$, or $\frac{VI}{IV}$ and without minifying the test-letters. If the minus sphere reduces the size of the letters, then the observer will know that he has added too much minus sphere and this would be a serious mistake if such a correction was prescribed.

Examples

Simple Hyperopia.—At 1 meter the observer finds that $+2.25$ sphere stops all movements in all meridians. With this correction the patient will read the $\frac{VI}{XII}$ line of letters indistinctly; then the observer begins to improve this vision by first adding -0.25 sphere, and then changing this -0.25 for a -0.37 and thus changes to a slightly stronger sphere which we will say is -1.25 when the patient reads $\frac{VI}{V}$ distinctly and says that the letters do not appear minified or as if they were at a great distance. The correction will then be $+2.25 \bigcirc -1.25$, equalling $+1.00$ sphere. (See Chapter XIX.)

Compound Myopia.—At 13 in. from the patient's eye a -2.00 cylinder at axis 180 stops all movement against the vertical meridian and previous to placing this cylinder there was a band of light in this 180 meridian that moved slowly against the mirror movement. The observer knows that this vertical meridian is now corrected for this distance of 13 in.; at the same

time it is also noted that the horizontal meridian is without any lens in position and no appreciable movement of the illumination. Then with this −2.00 cylinder in position at axis 180°, the patient is told to look at the test-letters across the room and is unable to see any of them. Under these conditions the observer need not stop to use a minus sphere as weak as 0.25 but may begin at once with a −1 sphere and then a −2 for he realizes after a little experience that when he obtained the point of reversal at 13 in. the patient was artificially myopic 3 diopters, and now with a −2 sphere in position and the visual acuity getting more acute, the observer does not go direct to the −3 sphere but changes from the −2 to a −2.25 and then to −2.50 and so on in quarter diopters until the normal visual acuity is obtained or the letters are not minified. It is necessary to draw the reader's attention to the fact that it may be impossible to give this eye full normal visual acuity with any glass as it often happens, especially in cases of progressive myopia that the retina is not capable of seeing $\frac{VI}{VI}$. The same holds true in cases of amblyopia, but here again the retinoscopic findings are the only ones that will guide to the proper selection of glasses in amblyopic eyes, as the patient is not always able to tell with any degree of certainty which lens makes him see better. The case just described will accept −2.75 ⌒ −2.00 cyl. axis 180.

Simple Myopia.—At the 1-meter distance the movement is against the movement of the mirror and adding −1.50 sphere all movement ceases. Then at 6 meters from the test-card with this correction the patient should see about $\frac{VI}{XII}$ and adding minus spheres beginning with −0.25, it will be found that −2.50 sphere will give standard vision of $\frac{VI}{VI}$ if the retina and media are healthy.

Simple Hyperopic Astigmatism.—At 2 meters the movement in the vertical meridian is very rapid and with a +0.50 sphere in position all movement ceases in this meridian, but there still remains a marked band of light which moves with in the 165

meridian, the band of light subtending the 75 meridian. A +1.50 cyl. axis 75 stops the movement of this band as the light from the mirror is made to pass through the 165 meridian. With this correction in position (+0.50 S. ○ +1.50 cyl. axis 75), the eye at 6 meters will read $\frac{\text{VI}}{\text{X}}$ slowly but by adding first − 0.25 and then − 0.50 the visual acuity comes to $\frac{\text{VI}}{\text{VI}}$+.

Mixed Astigmatism.—At 2 meters from the eye the vertical meridian does not reveal any movement of the illumination but the horizontal meridian requires a +2.25 cyl. axis 90. At 6 meters a −0.50 sphere added gives normal visual acuity and the correction is −0.50 ○ +2.25 cyl. axis 90.

Conclusions.—As this method of finding the correction is without the use of a cycloplegic, the reader must bear in mind that the ciliary muscle is very prompt to act and especially so when each eye is tested separately; therefore the writer would impress upon the reader to always test the two eyes together after he has obtained the correction for each eye separately and it will frequently be found that, when the two eyes are used together with their respective corrections, hyperopic eyes will accept more plus sphere and myopic eyes less minus sphere than when each eye is tested separately. Furthermore, the writer is more and more partial to a long range finding and resorts constantly to a distance of 85 ft. for his final findings before writing the prescription (see Fig. 150).

CHAPTER XXII

PRESBYOPIA.—APHAKIA.—ANISOMETROPIA.—SPECTACLES

Presbyopia.—The word presbyopia (from the Greek, πρέσβυς, "old;" ὦψ, "eye") literally means old sight, and patients at the age of 45 or more years are universally recognized as presbyopes, and the condition of their eyes as presbyopic. There is no exact age limit as to when presbyopia shall begin, the advent of presbyopia being controlled by the character of the ametropia and physical condition of the eyes themselves. Presbyopia may be described in several different ways, according to the cause; *i.e.*:

1. Old sight.
2. The condition of the eyes in which the punctum proximum has receded to such a distance that near vision (close work) is impossible without the aid of convex lenses.
3. The condition of the eye in which the lens fibers have become more or less sclerotic, and, as a consequence, the lens loses some of its inherent quality of becoming more convex during contraction of the ciliary muscle.
4. The condition of the eye in which the power of the ciliary muscle has become weakened.
5. The condition of the eye in which the power of accommodation is diminished at the same time that the lens fibers become sclerotic.
6. The condition of the eye in which two different refractions (not necessarily two pairs of glasses) are required, one for distance and one for near vision.
7. The condition of the eye in which one pair of glasses will not answer for distant and also for near vision.

8. Presbyopia may be described as the condition in which nature has instilled a slowly acting but permanent cycloplegic (the term cycloplegic is used here in a general sense).

Causes of Presbyopia.—1. *Age.*—It is a well-established fact that in childhood the center of the lens begins to harden, becomes sclerotic or sclerosed, to form a nucleus; and this process continuing very gradually from the center to the periphery usually eventuates in complete sclerosis at 60 or 75 years. The term sclerosis must not be confounded with opacity.

2. *Disease.*—Ordinarily, presbyopia, as applied to the lens, should be recognized as a physiologic process, as a penalty for growing old, though it is a condition which may be hastened by disease. Any disease, therefore, which will cause the nutrition of the lens to suffer must eventually interfere with its ability to become more convex during accommodation. The most common ailments that tend to this result are rheumatism, gout, Bright's disease, diabetes, lithiasis, la grippe, etc. Any disease which will weaken the ciliary muscle will produce presbyopic symptoms.

Presbyopic Near-points.—The near-point and power of accommodation in a healthy emmetropic eye, or a healthy eye made emmetropic by the addition of correcting lenses, is as follows for certain ages:

Age	Near point	Power of accommodation	
40 years	22 cm.	4.50	diopters
45 years	28 cm.	3.50	diopters
50 years	40 cm.	2.50	diopters
55 years	55 cm.	1.75 or 2.00	diopters
60 years	100 cm.	1.00	diopters
65 years	133 cm.	0.75	diopters
70 years	400 cm.	0.25	diopters
75 years	∞ cm.	0.00	diopters

Ordinarily, the average adult holds a newspaper or book at 33 cm. (13 in.) from his eyes when reading; and if he is 40 years of age and emmetropic, or is made emmetropic with glasses, he would be using 3 D. of his normal 4.50 of accommodation,

which would leave a reserve power of 1.50 D.; and in this condition, other things being equal, he can maintain a reading distance with comfort. In fact he could, by using all of his 4.50 D. of accommodation, see objects as close as 22 cm., but not for any great length of time, as the ciliary muscle would soon relax.

This same patient at 45 or 46 years of age will have lost 1.00 or 1.50 D. more of his accommodation, and now has only about 3 or 3.50 left; and if he uses all of it at a working distance of 33 cm., the ciliary muscle soon yields. In fact, the ciliary muscle cannot be held in such a state of tension without causing all sorts of pains and aches and reflex disturbances; and the ciliary effort relaxing suddenly, the near vision blurs, and the work or reading or sewing must be put at a greater distance to obtain relief, or else the effort must be abandoned.

Symptoms of Presbyopia.—The principal symptom is that which indicates a recession of the punctum proximum, the patient stating that there is an inability to maintain the former reading, writing, or sewing distance, and that all near-work must be held at a greater distance than formerly. Symptoms of accommodative strain may be present if the patient endeavors to force the accommodation to its maximum.

Diagnosis.—The age of the patient and the history of having to hold reading matter at an uncomfortable distance; or a history of good distant vision and an inability to retain clear near vision—small objects, to be seen, must be held far away or "at arm's length."

Correction of Presbyopia.—The presbyopic state represents a class of patients for whom glasses may be prescribed by the manifest refraction, although there are exceptional cases in which a quick cycloplegic will be necessary when an amount of astigmatism or cylinder axis is uncertain. When any cycloplegic is used for estimating the refraction in a presbyope its effect should be counteracted by the use of a myotic before the patient leaves the oculist's office.

For a working, reading, writing, or sewing distance of 33 cm. (13 in.), the writer makes it a rule to ***add to the distance correction*** at 45 years of age a +1 sphere; at 50 years of age, a +2 sphere; at 55 years of age, a +2.50 sphere; and for 60 or more years, a +3 sphere.

The following table for emmetropic eyes shows these additions for the different years, and also the near- and far-points *with* these additions as well as the range of accommodation or "play" between the near- and far-points. It will be observed that the range of 78 cm. at 45 years rapidly diminishes in the succeeding years, until at 60 there is a play of only about 3 in., and at 70 the range is practically gone.

Years	Add.	Near-point	Far-point	Range
45	+1.00	22 cm.	100 cm.	78 cm.
50	+2.00	22 cm.	50 cm.	28 cm.
55	+2.50	23 cm.	40 cm.	17 cm.
60	+3.00	25 cm.	33 cm.	8 cm.
65	+3.00	27 cm.	33 cm.	6 cm.
70	+3.00	30 cm.	33 cm.	3 cm.
75	+3.00	33 cm.	33 cm.	0 cm.

Because a patient is 50 years of age does not signify that he will be able to read at 33 cm. with a pair of +2 spheres, or because he is 60 years of age that he can use his eyes at 33 cm. comfortably with a pair of +3 spheres; on the contrary, this rule that the writer has given applies only to cases of emmetropia. It often happens that presbyopic patients state that they do not want glasses for distance; that they do not need them; that all they wish is a pair of glasses to use at near-work, reading, etc. When the vision is taken in such cases, it may be found to be $\frac{VI}{VI}$ or approximating $\frac{VI}{VI}$; but the young ophthalmologist must not be thrown off his guard by this record, as it has already been stated that a vision of $\frac{VI}{VI}$ does not by any manner of means prove the existence of emmetropia. Let the surgeon make it *a constant rule in every case of presbyopia to always carefully estimate the amount of the distance ametropia first, no matter how weak or what its form (sphere or cylinder)*, and to the

findings thus obtained add the plus sphere which will be required for the working distance or point at which the patient wishes to see clearly.

Illustrative Cases.—CASE I.—Accepts +0.50 sph. for distance. At 45 years this case would require +1.50 sph. for reading at a distance of 33 cm.; at 50 years, +2.50 sph.; at 55 years, +3 sph.; and at 60 or more years, +3.50 sph. Only one pair of glasses is necessary, and these for near-work only. It will not be necessary to wear such a weak correction as 0.50 for distance, especially as there is no discomfort with infinity vision.

CASE II.—Accepts +2 sph. for distance; at 45 years these eyes would require +3 sph.; at 50 years they would require +4.00 sph.; and at 60 or more years they would require +5 sph. Two pairs of glasses or bifocals would be indicated in this case.

CASE III.—Accepts −1.00 sph. for distance; at 45 years this patient could read without any glasses, as −1 for distance would be neutralized by the +1 required for reading. At 50 years, however, the patient would require a +1 sphere for near, and at 55 a +1.50, and at 60 years a +2 sphere. Case II required two corrections, one for distance and one for near, and the same may be said about Case III; but in this latter instance there was a time at 45 years when there was no necessity for glasses for the near-work, as the patient's eyes were in a suitable condition of refraction to read without them.

CASE IV.—Accepts −3 sph. for distance. At 45 years would require −2 sph. for reading; at 50 years would require −1 sph. for reading; and at 60 years can read ***without*** any glasses. Such a patient says he has got his "second sight."

CASE V.—Accepts +0.50 cyl. axis 180 for distance and requires the usual additional spheres for the increasing years for his reading distance. This patient should have bifocal lenses.

CASE VI.—Accepts +1.00 sph. $\bigcirc$ +1.00 cyl. axis 180 for

distance and requires the spheric additions as the years increase. Two pairs of glasses or bifocals should be prescribed.

CASE VII.—Accepts -1 cyl. axis 90 for distance, and requires $+1$ cyl. axis 180 to read with at 45 years of age; at 50 years he requires $+1$ sph. $\bigcirc$ $+1$ cyl. axis 180; and at 60 years requires $+2$ sph. $\bigcirc$ $+1$ cyl. axis 180. At 45 years of age this patient is commonly spoken of as having simple myopic astigmatism for distance (against the rule) and simple hyperopic astigmatism for near (against the rule also); two pairs of glasses or bifocals are indicated after 45 years of age.

CASE VIII.—Accepts -1.00 sph. $\bigcirc$ -1.50 cyl. axis 180 for distance, and at 45 years will need -1.50 cyl. axis 180 for reading; at 50 years will require $+1.00$ sph. $\bigcirc$ -1.50 cyl., axis 180°; at 60 years, $+0.50$ sph. $\bigcirc$ $+1.50$ cyl. axis 90°.

Two pairs of glasses or bifocals should be used after 45 years of age. At 45 years this patient has a compound myopic correction for distance and simple myopic astigmatism for near; at 50 years the correction for near is that of crossed cylinders (mixed astigmatism); and at 60 years the near correction is that for compound hyperopic astigmatism.

CASE IX.—Accepts -1.00 sph. $\bigcirc$ $+2$ cyl. axis 90 for distance (mixed astigmatism); at 45 years, $+2$ cyl. axis 90 is required for reading; at 50 years, $+1.00$ sph. $\bigcirc$ $+2.00$ cyl. axis 90. Two pairs of glasses are required. At 45 years the distance correction is for mixed astigmatism and the reading correction is for simple hyperopic astigmatism.

CASE X.—Accepts -2.00 cyl. axis 180 for distance; at 45 years requires a mixed astigmatism correction for near; at 50 years, a simple hyperopic astigmatism correction; and a compound hyperopic correction at 60 years.

In the above illustrative cases the working distance has been calculated at 33 cm., or 13 in.; but as some patients use their eyes at a greater or less distance than this, the additional convex lenses must be calculated accordingly. For instance, the weaver at 55 years of age who requires $+2$ sph. for distance

could not see to weave at 50 cm. if +2.50 sph. were added to his distance correction, and all he needs is +3 for his working distance. Or the diamond cutter who wishes glasses to see his work at 8 in., if he accepted −1.00 sph. for distance, he would require +2 sph. at 45 years of age.

In conclusion, there are three facts in the refraction of presbyopic patients that should receive attention:

1. Many accept a weak plus cylinder (+0.50 at axis 180) against the rule. This is presumptive evidence that the astigmatism is acquired, is lenticular, and is due to the sclerotic changes previously mentioned. The only positive way to prove this fact is by the retinoscope, and by the absence of corneal astigmatism with the ophthalmometer. If the case has been previously refracted by the same surgeon, his record will also confirm this extremely interesting occurrence. According to able authorities, hyperopic eyes become more hyperopic after the age of 70 years, and emmetropic eyes may become hyperopic, and myopic eyes less myopic, from the same sclerotic or shrinking process which takes place in all the ocular tissues as a result of senility. The method of correction by glasses, however, is just the same, and that is to correct the distant vision first and then add the near correction.

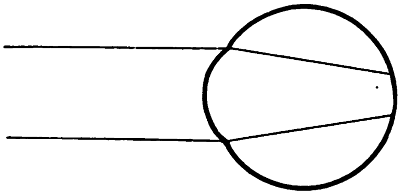


FIG. 298.

2. An attack of glaucoma may precipitate presbyopic symptoms, so that when a presbyopic patient asks for frequent changes in his corrections, this complication should be borne in mind.

3. The swelling of the lens which occasionally precedes the formation of some forms of cataract should be remembered when the patient develops symptoms of myopia; *i.e.*, a reduction in the strength of convex glasses.

Aphakia (ἀ, priv.; φακός, "lentil") literally means an eye "without a lens" (see Fig. 298). An eye which has had its lens dislocated has been erroneously spoken of as aphakic. The absence of the lens means a total absence of all accommodation, no matter what the age of the patient may be.

Causes.—Aphakia may be congenital, but in most cases is the result of removing the lens by operation.

Diagnosis.—Aphakia may be diagnosed by inspection— *i.e.*, corneal scar, depth of anterior chamber, tremulous iris, coloboma of the iris, opaque capsule whole or in part, erect corneal image, with absence of lenticular images, and by the patient's history.

The ametropia of an aphakic eye depends in great part upon the previous refractive condition of the eye, and also upon the kind of operation that was performed for the removal of the lens. It has been calculated that an eye, to be emmetropic after the removal of its lens, would have to be myopic at least 12 diopters. If this is always true, then the correcting lens which is selected by an aphakic eye is a guide to its former ametropia. An eye which selects a weak plus sphere would, therefore, have been myopic before the operation; and if about a +12 S., its previous refraction approximated emmetropia; if a plus sphere stronger than 12, then the previous refraction was very likely hyperopia.

An eye which has had its lens removed by absorption (needling) is not likely to be astigmatic; whereas, when the lens has been removed by extraction, astigmatism against the rule of one or more diopters almost invariably results, and the axis of the correcting cylinder generally coincides with the points of puncture and counterpuncture in the cornea. If a patient had 2 or 3 D. of myopic astigmatism with the rule, this would be neutralized by the corneal section.

Correction of Aphakia.—As in presbyopia, two corrections are necessary—one for distance and one for near. Astigmatism

must always be looked for and carefully corrected, especially if the lens has been removed by extraction.

CASE I.—

O. D., +8.00 sph. ⊂ +3.00 cyl. axis 10°. $V = \frac{VI}{X}$
O. D., +11.00 sph. ⊂ +3.00 cyl. axis 10° = reading at 33 cm.

This patient was presumably myopic before operation.

Heterometropia (*ἕτερος*, "different;" *μετρον*, "a measure;" *ὤψ*, "the eye") literally means that the ametropia of the two eyes is different in character; examples, O. D. +1 D. and O. S. −1 D., or O. D. +3 cyl. axis 90° and O. S. −3 cyl. axis 180°, or O. D. −5 D. and O. S. −5 cyl. axis 180°, etc.

Antimetropia, a subdivision of heterometropia, is that condition in which one eye is hyperopic and the other myopic.

Anisometropia (*ἄνισος*, "unequal;" *μέτρον*, "a measure;" *ὤψ*, "the eye") literally means that the ametropia of the two eyes is *the same in character* but of unequal amount. Examples, O. D. +2 D. and O. S. +6 D., or O. D. −0.50 D. and O. S. −5 D., or O. D. +3 cyl. axis 90° and O. S. +6 cyl. axis 90°, etc. This condition may be slight or one of the most extreme conditions imaginable.

For instance, if both eyes have compound hyperopic astigmatism, they are not considered as heterometropic, even if the sphere and cylinder are of different strength in the two eyes. Bearing this distinction in mind, the percentages already given for myopia, hyperopia, the different astigmatisms, etc., have been calculated accordingly, that for heterometropia being about 13 per cent.

Causes.—Usually the condition is congenital, or it may be acquired.

Difficulties.—Two difficulties are encountered when ordering glasses for cases of anisometropia, antimetropia or heterometropia: (1) The lens for one eye may be concave and that for the other may be convex, or both eyes may require a convex or both may require a concave lens, but one very much stronger

than the other; under these circumstances, when the eyes are rotated there will be a prismatic result of different amount in each eye, and this may mean diplopia, or at least an exertion on the part of the extra-ocular muscles to prevent diplopia which will cause dizziness, nausea, headache, etc. (2) With lenses as just mentioned, the size of the two retinal images will not be exactly the same, and this will mean an interference with clear binocular vision.

For purposes of study, the writer would divide cases of heterometropia, antimetropia and anisometropia into four different classes:

Class I.—This class embraces those cases in which the difference in the ametropia between the two eyes is very slight or does not exceed 2 diopters. In fact, there are very few pairs of eyes that are not slightly anisometropic; such eyes usually receive their exact corrections with comfort, regardless of the condition.

Class II.—Cases that come under this head also accept their exact correction for each eye, but do not attempt binocular fixation, and may never suffer the least inconvenience; these cases are extremely rare. They do not complain of diplopia, as they have learned to ignore the false image. Cases of alternating squint, one eye myopic and the other eye hyperopic, may be included in this class.

Class III.—This is a class which will accept the exact correction before one eye only, and the eye which has the greatest amount of ametropia will refuse almost any lens except the very weakest. The eye that has the most ametropia is often quite amblyopic.

Class IV.—This class includes young children especially; cases of squint. In children the correction for each eye as found by the static refraction is usually accepted.

The Prescribing of Glasses in Cases of Heterometropia, Antimetropia and Anisometropia.—Excluding Class I, there is no fixed rule to follow when ordering glasses in decided cases of

heterometropia, antimetropia or anisometropia, and, in fact, such eyes are a constant study to the most able ophthalmologist. The younger the patient, however, the more likelihood of a favorable result from the careful selection of a glass for each eye; but when the patient is an adult and has never worn correcting glasses, it becomes a very serious question as to what glasses to prescribe that will give satisfaction. As good results are to be expected in children, they should receive the most careful retinoscopic refraction. The child comes under observation on account of a squint, and an operation for the deformity is often demanded; but the operation must be refused until the ametropia has been carefully treated. Glasses having been prescribed, the squinting eye is put to work to develop its seeing qualities which have been permitted to lie dormant for want of a proper glass. To do this, the "good" eye is shielded or blinded with a handkerchief tied over it, or a blinder (see Fig. 291) placed over its correcting lens, for an hour or two each day, and in this way an attempt is made to bring the vision in the squinting eye up to that of its fellow (see page 287).

Or another way to develop the vision in the squinting eye is to use a cycloplegic in the "good" eye, so that the squinting eye must do most of the work. This is rather trying to the little patient, and often means the additional use of dark glasses. As a rule, the "good" eye has the least amount of ametropia, but occasionally the reverse condition may exist.

In a case like the following, the little girl, five years of age, was brought on account of convergent squint in O. S., which developed or commenced to appear when ten months of age, and the parents attributed it to the habit of sucking her thumb at the time of being weaned. Refraction, with atropin as the cycloplegic, and obtained with the retinoscope, showed O. D., $+2.00$ sph.; O. S., $+4.00$ sph. $\bigcirc$ $+1.00$ cyl. axis 75°.

This child developed the squint on account of the monocular astigmatism and because it could not accommodate sufficiently with the left eye. To avoid diplopia at the same time that the

eyes were converging, the left eye naturally turned inward. With correcting glasses, and practising as above directed, the squint entirely disappeared, and vision one year later was $\frac{VI}{V}$ in each eye with the correcting glasses. If the glasses are laid aside for any length of time, the squint returns. This child must wear the glasses or have "squint."

To make sure that no injustice is done to an apparently amblyopic eye in an adult (Class III, page 373) where amblyopia exanopsia has existed for many years and nothing has been done to improve its correction, the writer makes it a rule to prescribe the exact correction for each eye, and at the time of ordering the glasses explains to the patient what the purpose and desire is, and that if there is any great amount of discomfort in any way, he must return and have any necessary change made in the glass. These patients should be kept under observation and the amblyopic eye given some sort of correction and improved as much as possible; the purpose being not to allow the eye to degenerate or grow more amblyopic, for if any accident should befall the "good" eye, then the amblyopic eye will often be a friend indeed.

Glasses for Presbyopes and Cases of Aphakia.—Unless the distant vision is improved or asthenopic symptoms are relieved by glasses, it will be sufficient to prescribe the near correction only. When a distant and near correction are required, they may be prescribed as two pairs of glasses in separate frames, or two pairs in one frame, known as bifocals. Bifocals, or what is equivalent to bifocals, are made in different ways.

1. **Franklin or Split Bifocals** (Figs. 299 and 300).—This form of bifocal consists of an upper and a lower lens, each with its individual center: the upper lens is for distance and the lower for near vision. Such lenses must have the frame all around the edges, so as to hold them in position. Bifocals of this kind are not in common use. The field of distant vision is limited by the unnecessarily large near correction, and where the two lenses come together there is apt to develop chromatic

aberration and a decided prismatic effect when the vision is directed through this space.

℞. O. D., +2.00 sph.
O. S., +2.00 sph.
SIG.—For distance.

℞. O. D., +4.00 sph.
O. S., +4.00 sph.
SIG.—For near.

DIRECTIONS TO OPTICIAN.—Make into Franklin or split bifocals.

2. Morck's Patent or "Perfection" Bifocals (Fig. 301).—These are a modification of the Franklin or split bifocals, and in place of having lenses united in a horizontal line, the near and distant lenses are fitted together with corresponding cres-

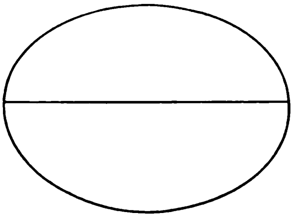


FIG. 299.

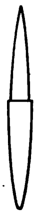


FIG. 300.

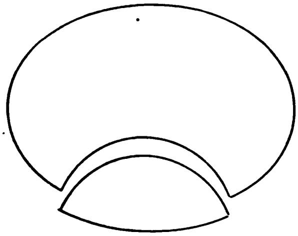


FIG. 301.

cent edges. This form of bifocal gives a larger field for the distance correction, and, like the Franklin, is much better for those who work in a damp atmosphere and cannot wear the cement bifocal. It is, however, more expensive than the cement form; but, like the Franklin, it often looks clumsy or heavy on account of the frame. "Perfection" or "Morck" bifocals must be signified in writing the prescription.

3. Cement Bifocals (see Figs. 302 and 303).—This is the most common form of bifocal and the least expensive in its original cost, as also when making changes in the near correction. This bifocal is made by cementing a segment of a small periscopic sphere on to the lower part of the distance correction. This periscopic sphere or disc or segment or scale, as it is called, has a prismatic quantity (see Fig. 303) suitable to the exigencies

of the individual lens to which it is cemented. The segment may be of any shape desired. Those in common use are shown in Figs. 302, 304, 305, and 306. It is cemented to the distance correction with Canada balsam. While this is the usual method of making a cement bifocal, yet it may be made by cementing a concave segment to the upper part of the near

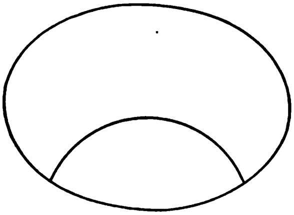


FIG. 302.

FIG. 303.

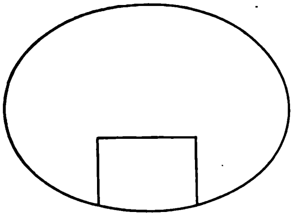


FIG. 304.

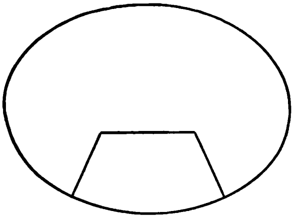


FIG. 305.

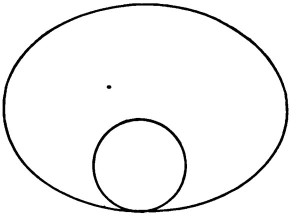


FIG. 306.

correction (Figs. 307 and 308). This form is not in common use.

℞. O. D., +2 S.
O. S., +2 S.
Cement on the lower part of the above O. D. and O. S., + 2.00 S.
SIG.—Make frameless bifocals.

Or,

℞. O. D., +4 S.
O. S., +4 S.
Cement on the upper part of O. D. and O. S., −2.00 S.
SIG.—Make frameless bifocals.

4. **Achromatic Bifocals** also known as Kryptok (Figs. 309 and 310[1]).—This form of bifocal is used principally in cases of

[1] Borsch patent.

aphakia where the plus sphere is quite thick and correspondingly heavy. It is made in one of two ways: (1) By grinding out a portion of the lower part of the distance correction (in crown glass) and cementing into the concavity a biconvex segment of flint glass. This form of bifocal is a combination of the "per-

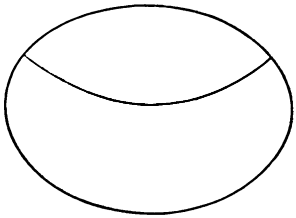


FIG. 307.

FIG. 308.

fection" and lenticular. (2) In place of grinding the concavity in one lens, as just described, this achromatic bifocal is also made by taking two planoconvex spheres and grinding out a concavity in each, and then inserting a convex sphere of flint glass, as shown in Fig. 310; these three lenses are then ce-

FIG. 309.

FIG. 310.

FIG. 311.

FIG. 312.

mented together, and when completed, look like the cement bifocal, as shown in Fig. 306. It is a matter for very careful calculation as to just how strong to make the flint glass segment, so that the result may be just exactly right. The merits of this bifocal are lightness and neat appearence. These lenses are very expensive.

5. Solid or Ground Bifocals (Figs. 311 and 312).—Lenses of this character are made in one piece by grinding on to the upper part of the near correction the necessary minus spheric correction for distance. They look neat, but are not always comfortable, on account of the resulting prismatic effect, which is especially apt to occur when the lens is convex, though this

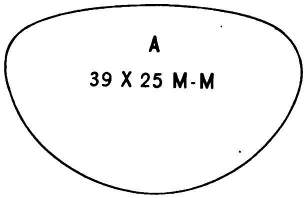


FIG. 313.

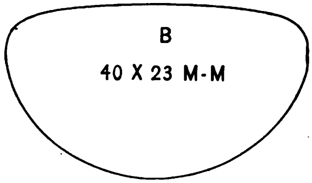


FIG. 314.

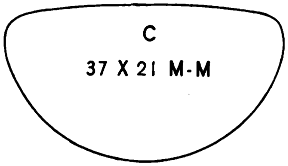


FIG. 315.

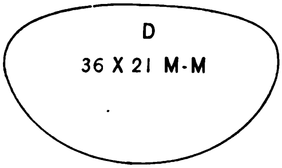


FIG. 316.

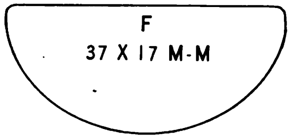


FIG. 317.

may not be so troublesome a feature when the lens is moderately concave.

6. Patients who require a very weak distance correction, and could do without it, sometimes accept it for the convenience of wearing bifocals; they do not wish to be annoyed by taking off or putting on a near correction, preferring to have the glasses where they can find them; business men especially. Other patients prefer to do without a distance correction, and will often use a near correction that has one-third or nearly one-

half of its upper part cut away, so that they can look over the near correction when they wish to see at a distance (see Figs. 313, 314, 315, 316, and 317). Myopes who do not need a near correction will wear their distance correction with its lower portion cut away, so that when they wish to see near at hand, they can look under the distance correction.

Patients who complain of seeing the lower edge of their

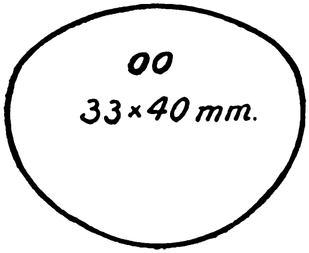


Fig. 318.

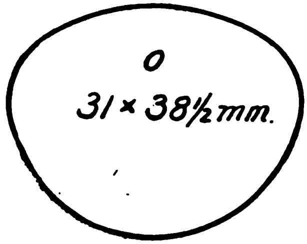


Fig. 319.

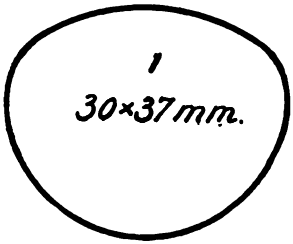


Fig. 320.

glasses when at near-work will enjoy the form shown in Figs. 318, 319 and 320. This is called a student lens.

7. Patients who require a distance correction, and cannot get accustomed to cement segments, and at the same time do not wish to change the distance correction, but prefer to keep it on all the time, can put on their addition for near vision in the form of hook or "grab" fronts of the same size as the distance lenses or reduced one-half in the vertical diameter. This is not always a good combination, as in every instance the lenses do not lie in contact with each other.

8. Lorgnettes may be used as a distance correction or as a substitute for hook fronts. Some myopic women who wear their near corrections constantly often carry lorgnettes which they hold up in front of the near correction to improve distant vision for a few minutes, or, wearing the distance correction, can use a plus lens in the lorgnettes for near vision.

9. Cases of monocular aphakia where the vision in the fellow eye is very defective can wear reversible frames, one lens for distance and the other for near—that is to say, a frame which has a free joint at the temples—and in this way they avoid bifocals, and can change the distance for the near correction, by turning the temple-pieces.

In some cases of aphakia when the lens is very powerful, a bifocal segment can sometimes be dispensed with, if the patient has a long nose, by adjusting the lens down from the eye and then holding the reading matter at the conjugate focus.

Toric Lenses.—These have already been described (page 92), but their use is of particular advantage to presbyopes and cases of aphakia, as these cases require lenses of less weight and also lenses which will enlarge the field of vision. Formerly a +15.00 S. D. ⊂⊃ +2.00 cylinder at axis 180 was made with the 2 cylinder next to the eye and the convex 15 was placed outward; this made a very thick and unwieldy lens, so that now with the toric lens this would equal a +7 S. D. next to the eye and the outer surface would have +10 cylinder in the vertical meridian and +8 in the horizontal meridian. Cases of presbyopia enjoy toric lenses also from the fact that the toric gives them a larger field. Patients with very long eyelashes appreciate toric lenses as the concave surface next to the eye gives the lashes a freedom of movement which they could not enjoy so well with the old sphero-cylinder lens. The toric lens also makes a much neater bifocal by allowing the segment or scale to be cemented on to the concave surface. *Young people with sensitive retinas do not, as a rule, enjoy toric lenses, as they permit peripheral rays to fall upon portions of the retinas which do not*

tolerate the increased stimulation. Presbyopes, as a rule, are not similarly disturbed.

General Considerations.—Before prescribing any pair of glasses for this class of cases, the patient should have the opportunity to wear the correction in the office for a short time, that he may study its effects; this is especially necessary (1) when the glasses are strong ones; (2) when there is monocular astigmatism; (3) when one lens is much stronger than the other (anisometropia); (4) when the astigmatism is asymmetric; or (5) when there is a strabismus, etc. The patient loses confidence (and the surgeon is not made happy) when the patient returns with his glasses in his hands and states that he cannot wear them—that they make him "dizzy" or "tipsy;" that the glasses make the pavement, houses, trees, people, pictures on the wall, chairs, tables, etc., all appear as if they were going to fall to one side. The surgeon should have anticipated all this, and assured the patient beforehand that, after a little perseverance and practice, this distortion (parallax) will disappear; and if not, then a change will have to be made in the glasses. Very often the whole difficulty is due to a want of proper centering of the lenses, presuming, of course, that the glasses ordered are perfectly correct.

Patients who require weak lenses—sphero-cylinders or cylinders alone—may at some time be informed that "the correction is but window-glass," and thus the surgeon may be put in disgrace as having prescribed for mercenary reasons, when in truth the glasses have already cured an old blepharitis or asthenopia. In ordering weak corrections, therefore, the character and purpose of the glasses should be imparted to the patient.

It is interesting to notice that strong glasses are usually ordered to improve the vision, and not always for the relief of asthenopia, whereas weak corrections are prescribed for the relief of headaches, etc., without any decided improvement in the vision which the patient can appreciate when looking at a distance, and many such patients will say they can see just as

well without their glasses. When strong plus spheres are prescribed for a child, it will do no harm to inform the parents of the character of the glasses, so that when a presbyope tries the child's glasses, the surgeon may not be accused of ruining the child's eyes by having ordered a pair of glasses strong enough for a grandmother to read with, and the child hurried off to a rival confrère to have the "outrage" rectified.

A patient who has fought against the inevitable, using headache powders, liver pills, etc., in the vain hope of not having to put on glasses, may still object to their use for various reasons. It may be that glasses will not add to the personal appearance or the parents may dislike the idea, fearing that "the oculist puts glasses on every patient," or that "the eyes will never be the same again," or that "the habit of wearing glasses, once established, can never be stopped." These and many other statements will serve to enliven the daily routine of ophthalmic practice. These objections having been met from the point of view of the patient's individual welfare and future good of his eyes, the next question that arises is what form of glasses shall be prescribed.

Spectacles.—The child is certainly a candidate for spectacles. The frames must be very durable, and preferably of 14-carat gold. Spectacle frames keep the lenses in position, and the lenses are then less liable to be broken than in the form of eye-glasses, and for most occupations are to be preferred. Occasionally, the shape of the nose will preclude the use of anything else but spectacles. When one lens is very heavy or both have considerable weight, or when one or both lenses are cylindric, with axes inclined, spectacles are certainly indicated.

Eye-glasses, also called "pince-nez," are for the adult, and may be prescribed when the lenses are not too heavy, or the cylinders too strong or their axes inclined. Eye-glasses are easily bent, and lose their exact positions before the eyes. For the young society girl nothing but the most delicately made eye-glasses will, as a rule, be accepted.

Bifocals.—These should not, *as a rule*, be prescribed if the lenses are very strong or the correction a complicated one, or the patient advanced in years and has never attempted them before, or if the patient is very portly or uncertain in his gait, or the vision is not brought close to the normal. Two separate pairs of glasses are to be recommended under these circumstances. When ordering any pair of bifocals, the patient should be cautioned and instructed that when looking downward, going up or down stairs, getting into or out of a conveyance, he is to look to one side or over the segment of the bifocal and *not* through it, otherwise he will be liable to make a false step or misjudge the distance, which might mean serious bodily injury, for which the surgeon does not wish to hold himself responsible.

Glasses for constant use should be placed perpendicularly or at an axis of about 5° to the plane of the face, with the optic centers corresponding to the pupillary centers when the eyes are directed to a distance. If the lenses are unusually strong and to be used principally at near-work, then it may be necessary to consider the advisability of having two pairs of glasses, one for distance and one for near, each with the centers to answer for the object in view. If only one pair of glasses has been ordered, and they happen to be very strong, then a pair of prisms in hook fronts may have to be used at the near-work, so as to counteract the prismatic effect of looking through the distance glasses during convergence. Glasses for near-work only should be put into a frame made especially for the purpose, so that the lenses may have an inclination in keeping with the downward turn of the eyes, and thus be perpendicular to the axes of the eyes, and the lenses should be decentered inward to equal the convergence. The one serious objection to bifocals in certain instances is that the glasses cannot be made with the inclination suitable for both distance and near vision, and very often there must be a compromise between the two.

The surgeon should make it a point to carefully inspect every

pair of glasses which he orders, as his painstaking efforts and best endeavors may be completely frustrated by poorly fitting lenses.

1. The lenses should neutralize (see page 96).
2. The optic centers should be at the points indicated.
3. The cylinder axes must be exact.
4. The lenses must be perpendicular or inclined to the front of the eyes, as necessary.
5. The distance of the lenses from the eyes should always be sufficient to clear the lashes; and if these are very long, they may have to be trimmed.
6. The most convex or the least concave surface of the lens should be placed away from the eyes. Or the most concave surface toward the eye.
7. The lenses should be of the correct size for the individual face. These and many other points for the average case must receive the careful consideration of the surgeon.

Tinted or Colored Glasses.—Except for the relief of photophobia following cataract extraction, mydriasis, or inflammatory diseases, or while using the eyes in bright light, electric, etc., the surgeon does not order colored glasses. Colored lenses are to be deprecated except in the cases just mentioned, as they only increase the tendency to photophobia instead of correcting it.

Fused Bifocals (Kryptok).—This variety of bifocal is also known as "invisible." It is not unlike the bifocal shown in Fig. 309. It is made by taking a small circular piece of flint glass and by great heat fusing one surface to a piece of crown glass; the crown glass is square in shape. This is the form in which the Kryptok Sales Company supply the opticians, who then grind the various curves to meet the conditions of the oculists' prescriptions.

Perimetric Lenses.—These are made to conform in outline to the normal field of vision as recorded by the perimeter, hence the name.[1]

[1] The writer described this form of lens before the Section in Ophthalmology of the College of Physicians of Philadelphia, in March, 1897.

The usefulness of the perimetric lens is limited to those cases in which the correction contains a plus cylinder and the lens is of moderate strength. It is not a lens that can be prescribed in myopia or aphakia. The purpose of the perimetric lens is to give a normal field and have the edge of the lens sufficiently removed that the patient may not be disturbed by seeing it. It certainly enlarges the field of vision, and in this way is a great advantage in certain occupations, playing the piano, etc. Fig. 319 or 320 may answer the same purpose, if properly centered.

Trifocals.—Occasionally, a patient is not content with bifocals, but will demand a focal point somewhere between

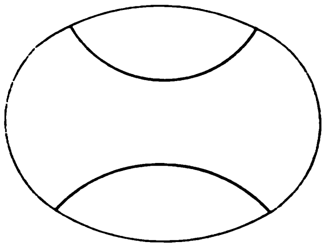


FIG. 321.

FIG. 322.

infinity and his working distance; this can be produced only by cementing two segments of different sizes and strengths on the intermediate correction (Figs. 321 and 322). Bookkeepers who have to work at large and lengthy ledgers find great comfort in this combination, though to be of special service the lenses must be made large. Example: +2.00 equals working distance at 1 meter. Minus 1 diopter added above equals infinity vision. +2.00 added below gives near vision at 13 in.

One-piece Bifocals or "Ultex."—This is not unlike the solid or ground bifocals, Figs. 311 and 312, but it is now made in the toric curve and of much neater and more delicate workmanship than the previous solid bifocal. This one-piece bifocal is frequently called "invisible" also, but there is really no bifocal that

is absolutely "invisible." Close inspection by reflected light will generally show where the two edges come together. Patients frequently think they will avoid seeing where the upper and lower corrections come together, but they will see it in any bifocal, and the term "invisible" applies to the friends of the patient, who cannot always see that bifocals are being worn. Patients of unknown age wearing bifocals of the "invisible" variety enjoy the fact that their friends still think that they are young (?).

CHAPTER XXIII

LENSES, SPECTACLES, AND EYE-GLASS FRAMES. HOW TO TAKE MEASUREMENTS FOR THEM AND HOW THEY SHOULD BE FITTED

The selection of the size and shape of lenses, the character of the spectacle and eye-glass frames and their adjustment, is the work of the optician. It occasionally happens, however, that the surgeon may not have an optician in his town, and will, therefore, have to take the necessary measurements himself and send them, with his prescription, to an optician in a neighboring city. This chapter is therefore added for the benefit of such surgeons. It is hardly necessary to state that the frames should be very carefully adjusted and the lenses centered to the patient's eyes. A lens improperly adjusted may utterly destroy the good effect of the most skillfully selected correction, giving discomfort to the patient and reflecting seriously upon the surgeon's ability. In fact, it is always well for the surgeon to personally inspect every pair of glasses which he may order.

Lenses.—These are spoken of as "eyes," and come in various sizes and shapes. They are spoken of as O, double O (OO), triple O (OOO), etc. (see Figs. 328, 329, 330, 331, and 332). Or sizes smaller than O are number 1, 2, 3, or 4 (see Figs. 323, 324, 325, 326). Different shapes and sizes are lettered A, B, C, D, F, or X (see Figs. 313, 314, 315, 316, 317, and 328). All these lenses are also marked in millimeters of breadth and length. The lenses for individual patients are selected according to the purpose for which they are intended, and particularly to be in keeping with the facial measurements. The size or "eye" O (39 $\times$ 30 mm.) is the usual size for the average adult,

and number 2, 3, or 4 is for a child. C, D, or F may be ordered for a presbyope who does not need a distance glass and who does not wish to be taking off the near correction to see at a distance; in other words, such a shaped lens can be looked over

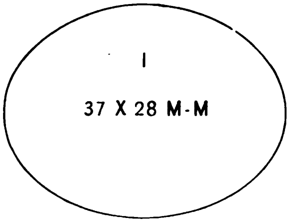


FIG. 323.

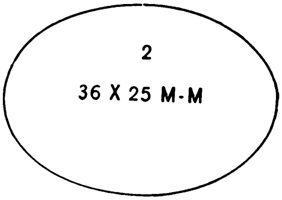


FIG. 324.

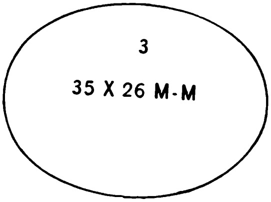


FIG. 325.

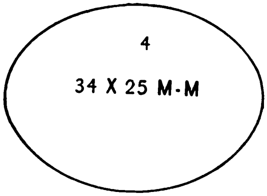


FIG. 326.

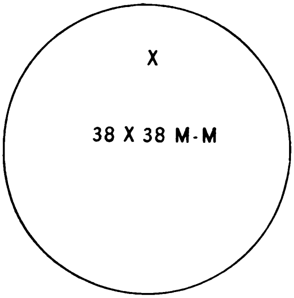


FIG. 327.

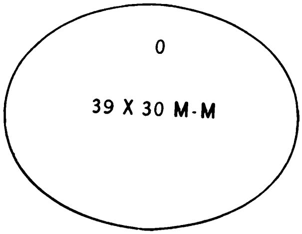


FIG. 328.

without any difficulty. Or the presbyope who requires a -2 for distance and can see to read without any near correction —being about 50 years of age—could have his minus lenses made in the shape of A, B, C, or D inverted, and, wearing this for distance, would look under it when he wished to see near

at hand. As a rule, the patient with a narrow face and short interpupillary distance will require a small "eye," whereas the patient with a broad face and long interpupillary distance will require a large "eye."

Spectacle Frames (Fig. 337).—These consist of a nose-piece (called the bridge) and temples (called sides). These are attached to the lenses ("eyes") by screws passing through holes

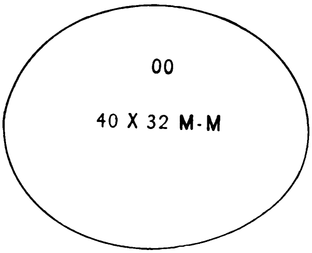


Fig. 3-9.

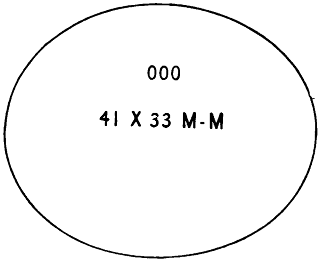


Fig. 330.

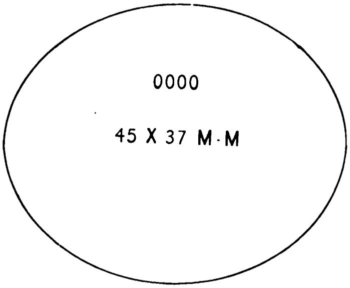


Fig. 331.

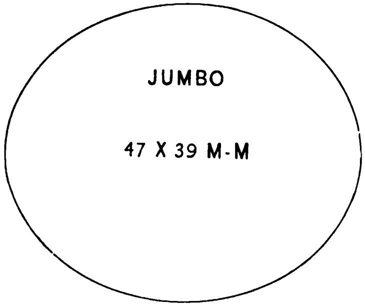


Fig. 332.

which have been drilled through them, making what is known as the frameless spectacles; or a wire is fitted around the lenses, to which the bridge and sides are attached with solder, forming the "framed" spectacles.

Eye-glass Frames (Fig. 338).—These consist of a spring and nose-pieces; the latter are called guards. Framed and frameless eye-glasses have the nose-pieces or guards attached to the lenses as in the spectacles.

How to Take Measurements.—There are three points that require particular attention: (1) The center of the lens should correspond with the center of the pupil; (2) the lens must be just far enough from the eyes to avoid the lashes, and if these are *very* long, they must be trimmed; (3) the lens must be at such an angle that the visual axis will be perpendicular to it.

First Measurements.—*The Interpupillary Distance.*—To accurately measure the distance from the center of one pupil to the center of the other is not always an easy thing to do, especially if the pupils are dilated; hence, it is good practice to measure this distance from the inner side or edge of one pupil to the outer edge of the other. This measurement can be made with

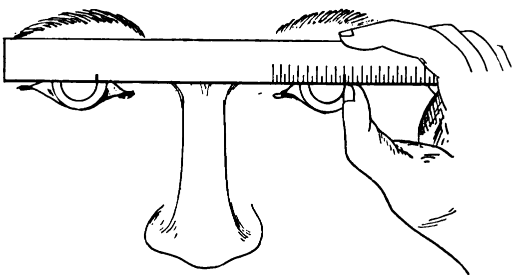


FIG. 333.

an ordinary rule divided to sixteenths of an inch or in millimeters, or with a special instrument for the purpose, called a pupilometer. The patient is told to look directly to the front, at an object across the room, and the surgeon, in front, with his head nearly in the line of sight, holds the rule across the patient's face, as close as the bridge of the nose or eyelashes will permit. With his thumb-nail as a marker, the surgeon gages the distance as indicated (see Fig. 333), which illustrates the conditions. In taking this measurement the surgeon should be at an arm's length from the eyes, for the reason that his own eye forms the apex of a triangle of which the eyes of the patient form the base, and the measurement is apt to be 2 or 3 or 4 mm. short if he gets too close.

If the glasses are to be worn for distance only, then the measurement must be for the full interpupillary distance, as the patient looks into infinity; but if the glasses are for near-work only, then the distance between the pupils must be correspondingly diminished, and the measurement taken as the patient looks at a near-point. If the glasses are to be worn for both near *and* far vision, for constant use, then the center of the lenses must be placed intermediate between the distance and near measurements.

Second Measurement.—*The Bridge.*—The regulation spectacle bridge is known as the saddle-bridge, and should conform to the exact shape of the patient's nose. It is intended to remain in just one place, and that is at the bridge of the nose

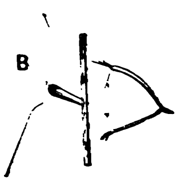


FIG. 334.

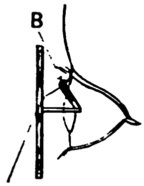


FIG. 335.

(see B in Figs. 334 and 335), the place where the nose begins to extend outward after passing down from the forehead. The points B and D, as shown in Fig. 336, represent the widest part or base of the bridge. A and R are the arms, which extend upward or outward and are fastened to the lenses. The length of the arms controls in great part the distance of the lenses from the eyes. To raise or lower the position of the lenses in front of the eyes, the posts or arms alone should be bent; *the bridge itself should never be tilted*, as its edge will cut into the skin of the nose; this is a most important consideration for the patient's comfort.

The Shape and Size of the Bridge.—To take this measurement, the surgeon should have a piece of lead-wire or thin, pliable copper-wire; the lead-wire is best. This wire is ac-

curately molded to the bridge of the patient's nose, the arms (A and R) are bent to the proper angle, and then the ends of the wire are curved or bent outward to show the plane of the lenses (see Fig. 336).

When the wire has been bent into place and the eyelashes do not touch at L and L, it is removed and placed on the under surface of a piece of paper, when an impression and lead-pencil tracing is made of it. If the measurement is not taken in this way, then the surgeon, with a pair of moderately blunt-pointed compasses, measures the breadth of the nose from B to D, and also the height of the bridge from F to E. The height of the bridge is spoken of as "out" or "in;" the former when F extends

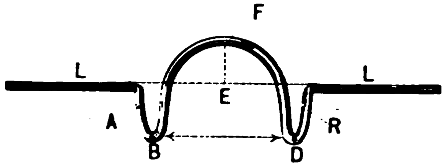


FIG. 336.

beyond the plane, and "in" when F is behind the plane of the lenses (see Figs. 334 and 335).

Another good way to take the foregoing measurements is to have several ordinary steel frames of different sizes and shapes, using whichever one of these seems to fit the best, and then making any additional alterations in the measurements that may be required.

Third Measurement.—This is the length of the sides or temples. This measurement is taken from the top of the ear to the plane of the lens, or to a horizontal line extending out from the eyelashes.

Fourth Measurement.—*The Size of the Lenses.*—This will depend upon the breadth of the face, the amount of space taken up by the bridge, its arms and attachments, as also the space occupied by the hinge and attachment of the temples.

Ordinarily, as stated before, the adult will select size O and the child No. 2.

The following blank is a good guide, as covering all the necessary measurements as referred to in this description for ordinary glasses.

STYLE OF BLANK FOR THE SURGEON TO FOLLOW WHEN ORDERING GLASSES FOR HIS PATIENT

Patient's Name..

Forward to..

....

℞. O. D.

O. S.

Distance of Near Frames.

Frames of..............................

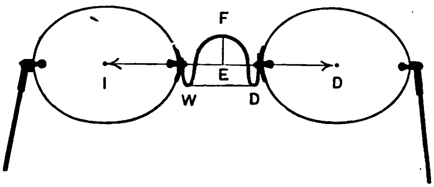


FIG. 337.

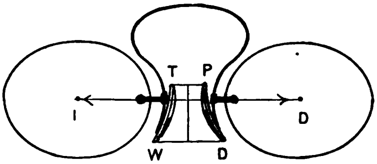


FIG. 338.

MEASUREMENTS

Spectacles	*Eye-glasses*
Interpupillary distance..............	Interpupillary distance..............
Height of bridge....................	Length of guard, W to T.............
Base of bridge......................	Width at Base, W to D..............
Shape of bridge (see drawing)........	Width at top, T to P................
Bridge, "in" or "out,".............	Length of arm of guards.............
Length of temples...................	Shape of spring (see diawing)........
Size of "eye".......................	Size of "eye".....................
Additional notes....................	
Date.............................	

.... M. D.

Styles of Frames.—If the glasses are to be worn constantly, they should be perpendicular or inclined about 5° from the perpendicular to the front of the eyes (see Fig. 339). They are spoken of as "distance" frames. If the glasses are to be worn

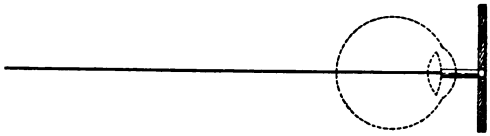


FIG. 339.

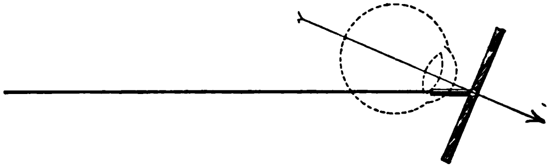


FIG. 340.

only at near-work, then the lenses should be tilted downward; this is known as the "near" frame (see Fig. 340).

Fitting Eye-glasses.—The position of the lenses applies equally to eye-glasses. The principal measurement is for the nose-pieces or guards and the arms or offsets from the guards (see Fig. 341). The width of the patient's nose where W and D, and also T and P, will press, depends, of course, upon the length of the guard itself—usually about 14 mm. It is also necessary to measure the position of the guards relative to the plane of the lenses; that is, whether the arms should be long, medium, or short, and whether they are "out" or "in" from the plane of the lenses.

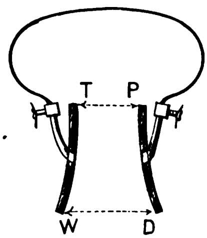


FIG. 341.

The style of spring may be that shown in Fig. 341, or one of the innumerable variety now found in the shops.

Bifocals.—The measurements for bifocals are the same as for the spectacle or eye-glass, except the size and shape of the

segment, and this should never extend above the median line of the lens, and seldom to it.

Quality of Frame.—These are made of silver, steel, aluminium or gold; the latter are always to be preferred, as more durable in every way. Silver and aluminium bend easily, and steel

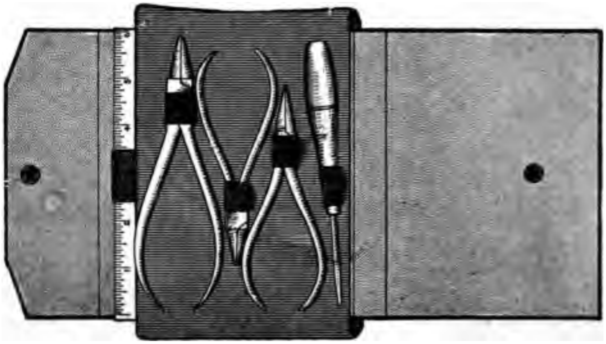


FIG. 342.—Handy pocket set.

frames rust and break. Every surgeon who does his own fitting should possess a small screw-driver, two pairs of delicate and yet strong pliers (one with round and the other with flat ends), and also a small rule. Fig. 342 shows a "Handy Pocket Set" which contains the necessary tools for the oculist who may have to take measurements and do the adjusting.

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